Reconsidering the Rules for Space Security

Nancy Gallagher and John D. Steinbruner

AMERICAN ACADEMY
OF ARTS & SCIENCES
RECONSIDERING THE RULES
OF SPACE PROJECT

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **APR 2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Reconsidering the Rules for Space Security**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **American Academy of Arts and Sciences,Cambridge,MA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**98**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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ISBN: 0-87724-070-1

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Please direct inquiries to:
American Academy of Arts and Sciences
136 Irving Street
Cambridge, MA 02138-1996
Telephone: (617) 576-5000
Fax: (617) 576-5050
Email: aaas@amacad.org
Visit our website at www.amacad.org

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Foreword

The rules that currently govern the use of space were codified in the 1967 Outer Space Treaty less than a decade after the first satellites were flown. They were designed to protect the common interest of all societies while regulating the competition for military advantage that dominated the pioneering programs of the United States and the Soviet Union. The rules assured universal rights of access and precluded sovereign jurisdiction over orbital transit. They permitted military support services, including reconnaissance, as long as the activity was peaceful, not aggressive. Orbiting weapons of mass destruction and using celestial bodies for military purposes were categorically prohibited, but sending nuclear missiles through space or placing conventional weapons there were not.

The United States was the principal sponsor of the original rules but has become the principal obstacle to their legal elaboration. In order to protect efforts to develop ballistic missile defense, the United States has refused since the 1980s to consider explicit rules prohibiting deliberate attack on space objects and the deployment of weapons in space. It has assertively blocked formal attempts to organize negotiations on those topics and has stood virtually alone against the rest of the world in doing so. The 2006 U.S. National Space Policy and supporting documents formulate the intention to dominate space for national military advantage and to control access by all other countries. The United States is spending tens of billions of dollars each year—far more than all other countries combined—to acquire advanced military space capabilities. The U.S. national security strategy outlines an intention to use these capabilities to eliminate emerging threats before hostile states or terrorist groups acquire dangerous technology—a standard of preventive protection that it does not propose to cede to any other country.

That officially stated formula violates the basic principles of the Outer Space Treaty and is inherently objectionable to all other countries. It is also technically and economically infeasible and surveys show that it would not command the support of the American public, a large majority of which wants additional legal provisions to protect satellites and prevent space weapons. But despite these apparent impediments, a policy of national military space domination prevails within the U.S. government at the moment and is being pursued with sufficient resources to mandate the concern of responsible security officials in other governments, especially those in China and Russia, but among U.S. allies as well. Informed observers can readily understand that the United States cannot dominate space to the extent imagined, but it can develop highly intrusive attack capabilities based on the use of advanced space assets. A predictable counter-reaction would be to hold at risk the satellites upon which the U.S. strategy of coercive prevention depends,

which would in turn make all space assets more vulnerable than they currently are. The U.S. vision is too unrealistic to drive a classic arms race but does threaten to provoke asymmetrical responses that would be legally and physically destructive.

This situation clearly requires a more penetrating discussion than has yet occurred and ultimately a more rational balancing of real interests. Assets in space are becoming increasingly vital in daily life not only in the United States but throughout the world as well. In pursuit of an image of dominance that would not be tolerated and could never be achieved, current U.S. space policy threatens services that are integral to the performance of the global economy as well as our own military capabilities.

The American Academy called upon two scholars to evaluate both the feasibility and desirability of U.S. military plans for space. Nancy Gallagher, the Associate Director for Research at the Center for International Security Studies at Maryland (CISSM), and John D. Steinbruner, a Professor at the University of Maryland's School of Public Policy and Director of CISSM, provide a comprehensive review of U.S. military plans for space, arguing that the current goal of establishing decisive military space "dominance" is no more feasible or desirable in a globalizing world where the United States is first among many countries with space capabilities than it was during the Cold War competition between two roughly equal space superpowers.

Gallagher and Steinbruner argue that the United States will not be able to "outspend and out-innovate all potential rivals in space." Moreover, they contend that the "costs of using military means to protect U.S. and friendly space systems against asymmetrical attacks" will outweigh the "benefits of seeking full-spectrum space dominance." For this reason, the authors urge the United States to abandon its current policies and to support international negotiations to build on the Outer Space Treaty by developing new rules that explicitly address the central problems of space security. These negotiated legal protections would prohibit deliberate interference with legitimate space assets, outlaw the deployment of weapons in space and other dedicated anti-satellite weapons, and define the legitimate limits of space-based support for military missions. Gallagher and Steinbruner conclude by highlighting some practical steps necessary for successful negotiations, including strategies for ensuring the equitable distribution of the costs of verifying compliance with these legal prohibitions.

Two events that occurred in mid-February, after the text of this monograph was completed, highlight the need for space security to receive urgent attention from the next U.S. administration. On February 12, 2008, at the Conference on Disarmament, Russia and China formally presented a draft treaty on "The Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Space Objects," and the Bush administration immediately reiterated its opposition to any new legal restrictions on its access to or use of space. Two days later, the Department of Defense announced plans to use a modified sea-based theater missile defense interceptor to destroy a malfunctioning U.S. spy satellite before it fell to Earth, which

it carried out on February 21, 2008. Regardless of what one thinks of the details of the Russian-Chinese draft treaty or the rationale that the Bush administration gave for destroying the satellite in order to preclude the possibility of its fuel tank landing on a populated part of the Earth, it is clear that military capabilities in space are advancing with no correspondingly serious effort to discuss, let alone to negotiate, how they should be used.

This paper is part of the American Academy's "Reconsidering the Rules of Space" project. The project examines the implications of U.S. policy in space from a variety of perspectives, and considers the international rules and principles needed for protecting a long-term balance of commercial, military, and scientific activities in space. The project is producing a series of papers, intended to inform public discussion of legitimate uses of space, and induce a further examination of U.S. official plans and policies in space. Other papers consider the physical laws governing the pursuit of security in space (spring 2005), challenges posed to the U.S. space program by current policies (spring 2005), and Chinese and Russian responses to U.S. space plans (spring 2008).

The Academy convened a workshop to discuss the current paper in September 2007. We join the authors in thanking the participants in this workshop for their insights. We also thank members of the Academy's Committee on International Security Studies for their thorough review of this paper in June 2007.

We acknowledge the excellent work of Phyllis Bendell, Christopher Davey, and Anne Read in helping to produce this report. We are, most of all, grateful to the authors for applying their knowledge and experience to these important issues.

The Rules of Space project is supported by a generous grant from the Carnegie Corporation of New York. We thank the Carnegie Corporation for its support and Patricia Nicholas for her assistance.

Carl Kaysen
Massachusetts Institute of Technology and Co-chair, Committee on International Security Studies American Academy of Arts and Sciences

Paul K. MacDonald
American Academy of Arts and Sciences

Acknowledgments

The Reconsidering the Rules for Space Security project is a collaboration between the Center for International and Security Studies at the University of Maryland (CISSM) and the American Academy of Arts and Sciences's Committee on International Security Studies (CISS). Over the past six years, CISSM and CISS commissioned a series of working papers and organized workshops to help the authors better understand the diverse technical, economic, legal, political, and strategic issues that shape space security. Martin Malin and Paul MacDonald organized the CISS side of the Reconsidering the Rules for Space Security project, and Jeffrey Lewis, Jaganath Sankaran, and Maranda Sorrells provided invaluable assistance on the CISSM side. This monograph represents our effort to integrate insights gained from this collaborative endeavor with the results of an intensive research program conducted at CISSM during the same time period.

We are particularly grateful to David Wright, Laura Grego, and Lisbeth Gronlund for writing *The Physics of Space Security* as a companion to this monograph intended to help anyone who is interested in space security but lacks a scientific background to understand the physical laws and technical facts that shape what is possible and what is desirable to do in space. We also benefited greatly from working papers by the following individuals: Nina Tannenwald on the High Seas analogy and its relevance to a rule-based regime for Outer Space; Ram Jakhu on legal issues associated with space security; Hui Zhang, Pavel Podvig, and Xavier Pasco on Chinese, Russian, and European perspectives; Neal Lane and George Abbey on challenges and opportunities for commercial and civilian space users; and David Mosher and Steve Fetter on the limits of using space to solve key military problems.

A number of people took the time to review earlier drafts of this monograph. We would especially like to thank John Logsdon, John Rhinelander, John Pike, Michael Moore, Henry Herzfield, Marcia Smith, Peter Hays, and Karl Mueller for their detailed comments and constructive efforts to help us communicate effectively to a readership that we hope will be very diverse in their knowledge of, and attitudes toward, the issues covered in this work. Naturally, differences of interpretation and emphasis remain, and we take full responsibility for the ideas expressed in this monograph.

Finally, we would like to gratefully acknowledge the financial and intellectual support provided by the John D. and Catherine T. MacArthur Foundation and the Carnegie Corporation of New York, without which, none of this would have been possible.

Acronyms

ABM	anti-ballistic missile
AFSPC	Air Force Space Command
ANGELS	Autonomous Nanosatellite Guardian for Evaluating Local Space
APS	American Physical Society
ASAT	anti-satellite weapon
BMDS	Ballistic Missile Defense System
CAV	Common Aero Vehicle
CBO	Congressional Budget Office
CD	Conference on Disarmament
CoC	[Hague] Code of Conduct
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
DARPA	Defense Advanced Research Projects Agency
DART	Demonstration of Autonomous Rendezvous
DOD	Department of Defense
DSP	Defense Support Program
EELV	Evolved Expendable Launch Vehicle
FALCON	Force Application and Launch from Continental United States
FIA	Future Imagery Architecture
FMCT	fissile material cutoff treaty
GAO	Government Accountability Office
GEO	geostationary orbit
GEOSS	Global Earth Observation System of Systems
GLONASS	Global'naya Navigatsionnaya Sputnikovaya Sistema [Global Navigation Satellite System]
GPS	Global Positioning System
HCV	hypersonic cruise vehicle
Intelsat	International Telecommunications Satellite Organization
ISR	intelligence, surveillance, and reconnaissance
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JDEC	Joint Data Exchange Center
JCS	Joint Chiefs of Staff

KE ASAT	kinetic energy anti-satellite weapon
LEO	low earth orbit
LOAC	Law of Armed Conflict
LTBT	Limited Test Ban Treaty (1963)
MDA	Missile Defense Agency
MEO	medium earth orbit
MHV	Miniature Homing Vehicle
MILSTAR	Military Strategic and Tactical Relay [Satellite]
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NFIRE	Near Field Infrared Experiment
NGA	National Geospatial Intelligence Agency
NRO	National Reconnaissance Office
NSC	National Security Council
NTM	national technical means (of verification)
NSSP	National Security Space Project
ORS	Operationally Responsive Space(lift)
OST	Outer Space Treaty (1967)
PAROS	prevention of an arms race in outer space
PPS	Precision Positioning Service
SA	selective ability
SAR	synthetic aperture radar
SBIRS	Space-Based Infrared System
SDI	Strategic Defense Initiative
SIA	Satellite Industry Association
SPACECOM	United States Space Command
SPOT	Satellite Pour l'Observation de la Terre (Earth Observation Satellite)
SPS	Standard Positioning Service
SROE	United States Armed Forces Standing Rules of Engagement
STRATCOM	United States Strategic Command
TOA	total obligation authority
TSAT	Transformational Satellite Communications System
UN	United Nations
UNIDROIT	United Nations Institute for the Unification of Private Law
vMFP	virtual Major Force Program
WMD	weapons of mass destruction
XSS	Experimental Satellite System

Introduction

Beneath a rich diversity of opinion about current security issues, a dominant fact sets the practical foundation for policy worldwide. For at least fifteen years the United States has been financing its military establishment at a rate roughly equal to the rest of the world combined. As a result of that disparity, U.S. operating capabilities are unique in the contemporary world and arguably in history as well. Any other country would require more than a decade of extraordinary investment to match the U.S. capacity to project military power over distance, and no other country is yet attempting to make such an investment. When the popular phrase "sole superpower" is invoked, disparity of investment is what it most plausibly means.

That disparity does not confer the ability to exercise global hegemony, as is sometimes casually imagined. For all the romance about wielding military power, it is in fact a ruinously inefficient means of accomplishing most constructive objectives. As has become painfully apparent in the occupation of Iraq, it is one thing to defeat an opposing military establishment and quite another to shape the behavior of an entire society. The United States could forcefully alter the established pattern of sovereign jurisdiction in only a few exceptional circumstances. Moreover, its capacity for major combined arms operations cannot be comprehensively applied to the smaller-scale, more widely dispersed patterns of violence that currently pose the most active forms of threat. Nonetheless, in specific instances of its choosing, the United States is capable of bringing decisive coercive force to bear, and that potential is a riveting security consideration not only for those countries with reason to fear the United States but also for those indirectly implicated.

Because the provision of security is a central obligation of all governments on which their legitimacy depends, the disparity of capability creates fundamental issues of sovereign equity and makes the operating principles of the U.S. military establishment a matter of strong international interest. Those countries that are members of the U.S. alliance system enjoy a higher standard of protection against external assault than those that are not, but as a consequence they are also more entangled in whatever the United States does. Countries outside the U.S. alliance system must rely on their own resources, and some bear a heavy burden to do so. Those countries that are assumed by the United States to be threatening are themselves threatened by the implications of that assumption. For the protected and disregarded as well as the threatened, disproportionate power requires a commensurate degree of reassurance.

Most of the world therefore finds troublesome the George W. Bush administration's rejection or revision of policies traditionally used to convey reassurance by imposing agreed restraint on the development and use of mili-

tary power. The United States withdrew from the Anti-Ballistic Missile (ABM) Treaty that was considered by Russia to be a defining feature of the mutual deterrence relationship and essentially imposed a replacement arrangement that subjects Russia to progressively increasing strategic disadvantage. The United States proclaimed the intention to initiate the use of force, including nuclear weapons if necessary, to prevent states or terrorist groups that it considers to be inherently hostile from acquiring technology that could be used for mass destruction, and it cited that rationale as justification for the forceful removal of Saddam Hussein's government. Undertaking the action against Iraq without international authorization violated the central rule of international security—the prohibition against aggression that the United States itself had defended in the 1991 liberation of Kuwait. Whatever is said or not said in official diplomacy, the combination of these developments has been disturbing to nearly all other countries and genuinely alarming to some.

In both instances the underlying security principles at stake were obscured by details of the specific situation. Russia chose to absorb the demise of bilateral strategic stabilization without immediate antagonistic reaction, and in the absence of dispute between the principal parties none of the countries indirectly affected—China, for example—had adequate standing to object. There was active protest against the invasion of Iraq but too little sympathy for Saddam Hussein to provide a good opportunity for pursing the broader implications. The two episodes provoked specific concern but did not generate extended debate about international security arrangements in general.

Smoldering international concern will nonetheless find occasions for expression. The Russian reaction to proposed U.S. missile defense installations in Poland and the Czech Republic has been amplified by these deeper concerns to a degree that threatens the basic elements of nuclear and conventional force restraint in Europe. The underlying issues of equity and the organizing principles of policy that either mitigate or exacerbate them are too abstract to be the primary focus of practical discussion. If they are to be engaged and seriously contested, they need to be embedded in some defining context that serves both to illuminate them and to command sustained attention.

Many issues might serve these purposes, but the regulation of space activities is especially significant among them. In conducting global military operations, the United States already heavily depends on observation, navigation, and communications services provided by space assets. U.S. planning documents project not only the development of more advanced military support satellites but also the introduction of anti-satellite weapons, space-based missile defense interceptors, and space-based global strike weapons. The stated purposes are to observe potentially hostile activities as they occur, to enable rapid counterattack, and to be able to deny similar capability to all other countries. If those aspirations were ever to be achieved, they would enable highly intrusive forms of coercion that could be undertaken without the burdens of occupation. Any country threatened by that prospect has reason to

ponder attacking the space assets on which the threat would depend, yet their efforts to develop anti-satellite options run a high risk of stimulating even greater U.S. military efforts to control and exploit space.

Fearing the destructive competition likely to be triggered under these circumstances, the attentive international community has been attempting to initiate negotiations to extend existing rules regulating military uses of space. This endeavor has been blocked largely by the refusal of the Bush administration to authorize the necessary negotiating mandate, but that refusal has not yet been broadly ratified. The American public is almost entirely unaware of current efforts to control space militarily, and many of the domestic constituencies that depend upon space activities do not appear to have examined the implications of the new U.S. space policy in realistic detail. Nor has the economic and technical feasibility of achieving complete U.S. military space dominance been the subject of comprehensive review by Congress, by a balanced independent commission, or by any other expert-level group that represents the broad array of interests at stake. There are good reasons to expect that the development of space will eventually become a prominent venue for engaging the general issues of international security and for working out the more refined principles of policy and rules of behavior that common interest is likely to require. Those reasons derive in part from basic features of the space environment, in part from formative history, and in part from projected trends of utilization.

FEATURES OF THE ENVIRONMENT

The physical requirements of initial launch and subsequent maneuver impose significant burdens on all space activities. Any object resting on the Earth's surface and therefore moving with the Earth's own rotational and orbital velocity must acquire nearly 8 km/sec additional velocity to achieve an orbit around the Earth. The cost of imparting that additional velocity has remained constant for several decades despite continuous efforts to reduce it. Once placed in a stable orbit, all objects of whatever mass can be retained in that orbit indefinitely with low-energy housekeeping maneuvers, but a large amount of energy proportionate to the object's mass is required to change the object's orbit. The heavier the object, the more expensive it is to launch in the first place and to maneuver out of its initial orbit. Some maneuvers, moreover, are more difficult than others. A proportionate change in altitude—distance to the Earth's surface—requires less energy to accomplish for a given mass than a comparably proportionate change in inclination—the angle at which an orbit intersects the Earth's equator. Since the energy required for maneuver must be provided by the object itself and adds to its initial launch weight, satellites have been designed to accomplish their purposes with as little weight and orbital maneuver as possible.

In practical terms all this means that satellite movements are observable and predictable, that they are limited in their ability to evade objects in intersecting orbits, and that they cannot be fortified against the high velocity colli-

sions that could result. This in turn means that satellites are inherently vulnerable to destruction. Billion dollar assets with advanced equipment can be disabled by much less sophisticated means—a fact that provides leverage to disadvantaged antagonists. Disruption is much easier to accomplish in space than constructive use.

Because mass matters disproportionately in these considerations, inherent vulnerability can be somewhat reduced by decreasing the size of satellites. Smaller objects are easier to launch and maneuver and are more difficult to identify and track. That option competes, however, with the aspiration to develop more advanced capabilities. Although the public record does not reveal exactly how that interaction is working out in technical terms, a reasonable presumption is that the balance of advantage between sophisticated use and crude disruption is not likely to be reversed anytime soon. Achieving dominance in space at feasible cost is doubtful for basic physical reasons. Correspondingly likely is that sophisticated utilization will depend on broad acceptance and therefore on equitable rules.

FORMATIVE HISTORY

The legal provisions and more informal operating principles that currently regulate space activity reflect these features of the environment. Because the rules of sovereign jurisdiction that regulate use of airspace would be impractical to apply at orbital altitudes, that temptation was quickly precluded despite competitive antagonism between the two original space-faring nations, the United States and the Soviet Union. Although each was initially worried that the other might claim national jurisdiction in order to deny the legality of satellite overflight, as they assertively did in the case of airspace, both instead endorsed the principle that sovereign jurisdiction cannot be extended to space. This principle was formalized in the 1967 Outer Space Treaty (OST) along with the positive corollary that space is the province of all humankind and can be freely used for peaceful, mutually beneficial purposes. The two strategic antagonists were primarily interested in the use of space to stabilize deterrence and support arms control, so they conceded that they would have to tolerate similar uses by other countries in order to protect their own activities. The fact that this mutual concession was largely spontaneous, requiring little initial discussion or formal negotiation, indicates the power of physical circumstance. Both countries realized that unconstrained pursuit of competitive advantage would effectively preclude the development of space for any constructive purpose.

TRENDS OF UTILIZATION

The constructive purposes of primary interest—Earth observation, communication relay, and navigation—were initially developed in the context of superpower competition. Much of the extensive investment necessary to undertake

space activities was originally provided by the superpowers' defense budgets.[1] The highest-priority U.S. satellites were for reconnaissance, and even the scientific space programs were initially more about prestige than research, intended to demonstrate the superiority of one system over the other. That initial investment, however, provided the basis for expanding both participants and purposes. By the end of 2007, around fifty countries, intergovernmental consortia, and nongovernmental organizations (NGOs) have at least one satellite in space, mostly for reasons that have more to do with economic performance and Earth monitoring than with military applications.[2] Satellite imagery and navigation services originally generated as by-products of military support have become integral to daily commercial activity, as have satellite-based communications services. Entrepreneurs exploring investment opportunities stimulate speculation that the primary sources of financing and the impetus for development could shift from government to private capital markets, as occurred in the computer industry some four decades ago. In principle, for example, a surge of demand for satellite broadband services or dramatic decreases in launch costs might generate the large capital flows and rapid product cycles characteristic of global markets.

Despite the apparent potential, however, these changing patterns of space utilization have not yet lived up to predictions made in the late 1990s that market forces would overwhelm military factors in shaping investment choices, technology development, and regulatory rules. Steep U.S. funding increases for military space acquisition undertaken since 2001 mean that the U.S. defense budget still provides the single largest source of investment in space, and that investment would have to be increased substantially more if the stated aspiration of military dominance were to be seriously pursued. The ever-increasing number of countries, companies, NGOs, and individuals who see space as playing a vital role in the realization of their hopes for a better future are, however, unlikely to be content to let the United States decide who should use space for what purpose.

If global market dynamics were to emerge, the context of policy would be substantially altered. Large-scale commercial investment almost certainly would depend on elaboration of the existing legal regime along lines that would be incompatible with a competition for military dominance. The natu-

1. Since the establishment of the National Aeronautics and Space Administration (NASA) in 1958, U.S. government spending on space activities per se has usually been roughly equally divided between NASA and DOD, with NASA somewhat higher during the campaign to put an astronaut on the moon, and DOD somewhat higher during the Reagan and George W. Bush administrations. These figures, however, do not include the large investment that DOD made during the 1950s and 1960s in ballistic missile technology that could be adapted for space launch or anti-satellite purposes. Historical budget data through fiscal year (FY) 2005 are in Appendix D-1A of the *Aeronautics and Space Report of the President: Fiscal Year 2005 Activities,* 101, http://history.nasa.gov/presrep2005.pdf.

2. The precise number depends on the counting rules used. The Union of Concerned Scientists' satellite database is available online at http://www.ucsusa.org/global_security/space_weapons/satellite_database.html.

ral hazards of space operations would alone require more advanced protective regulation, especially to control the accumulation of debris in the more important operating orbits, and the possibility of deliberate interference would have to be addressed as well. A sustained American effort to dominate space would create a potentially strong incentive for the strategically disadvantaged to use commercial assets as hostages to fend off intimidation and even to force accommodation. One can debate how likely that would be, but prudent investors predictably would require explicit legal reassurance.

In general, it is reasonable to prepare for a more extensive and more penetrating debate over space policy as a means of engaging the yet more fundamental issues of international security generally. What follows is an effort to encourage that preparation by reviewing the relevant history, by assessing the viability of the dominance concept, and by exploring constructive alternatives.

The Historical Legacy

Access to space originally became available as a result of programs to develop ballistic missiles and build reconnaissance satellites in support of strategic confrontation between the United States and the Soviet Union. From the outset, however, space technology, like nuclear energy, was recognized as having beneficial as well as destructive applications and as ultimately becoming accessible to many countries. To an extent that is not well appreciated today, the United States used its leadership position in the early decades of the space age to promote informal understandings and formal rules that facilitated desirable uses of space and minimized potential problems.

ORIGINS OF THE RULES FOR SPACE

A 1950 RAND report that has been called "the birth certificate of American space policy" underscored the practical importance of legal justification.[3] The report emphasized the "vital necessity" of improved intelligence about the closed Soviet Union but cautioned that because the existence of spy satellites could not and should not be kept secret for long, creating a favorable context in which to use the new technology would be just as important as developing the capability itself. The authors recognized that reconnaissance satellites would pose a dilemma for Soviet leaders, who would see the loss of secrecy as a major violation of sovereignty and a quasi-permanent threat to security. But U.S. satellites would be too high to shoot down, at least initially, so Soviet response options would be limited to legal and diplomatic protests, attacks on ground stations, or total war. If the United States paid careful attention to political and psychological issues associated with space technology, the RAND report argued, it could constrain the Soviet counterreaction, strengthen deterrence, reduce Politburo resistance to international inspections of atomic installations, and possibly elicit a radical reorientation of Soviet behavior along more cooperative lines.[4]

To establish a favorable political context and set a precedent that could be used to legitimize future reconnaissance satellites, the Eisenhower administration decided to start by launching a scientific satellite even though military alternatives would have been ready sooner. The launch coincided with the International Geophysical Year, and the satellite, launched using a modified research rocket, was placed in an orbit that would not traverse the Soviet

3. Walter A. McDougall, *The Heavens and the Earth* (Baltimore: Johns Hopkins University Press, 1997), 108.

4. Paul Kecskemeti, "The Satellite Rocket Vehicle: Political and Psychological Problems," RAND RM-567 (October 1950).

Union.[5] The U.S. decision to wait until it could launch a scientific satellite allowed the USSR to create a public sensation by being the first country to launch a man-made satellite, but one of Eisenhower's military advisors remarked that the Soviets "had done us a good turn, unintentionally, in establishing the concept of freedom of international space."[6] That judgment reflected an appreciation that space could not be physically controlled by military force in the manner that territory on Earth or the airspace over it is controlled.[7] Some accommodation in space for mutual benefit would be necessary even in the context of global confrontation. Khrushchev appeared to have recognized this logic, as well. After the Soviets shot down an American U-2 reconnaissance plane in May 1960, Charles de Gaulle asked about cameras in the Sputnik orbiting over France, and Khrushchev said that he objected to airplane overflights, not satellite-based surveillance.[8]

In the Cold War atmosphere that prevailed at the time, Eisenhower's judgment was initially subjected to political attack.[9] Senator Lyndon Johnson

5. McDougall, *Heavens,* 122–123. The key policy document is "Statement of Policy on U.S. Scientific Satellite Program," National Security Council (NSC) doc. 5520 (May 20, 1955), 6–20 in *Presidential Decisions: NSC Documents,* ed. Stephanie Feyock (Washington, DC: The George C. Marshall Institute, 2006) (hereinafter referred to as NSSP, *NSC Documents*). The history of the CIA's role in shaping early U.S. space policy to promote the "freedom of space" principle is detailed in Dwayne A. Day, "Tinker, Tailor, Satellite, Spy," *The Space Review,* October 29, 2007, http://thespacereview.com/article/989/1.

6. The adviser was Donald Quarles, Eisenhower's assistant secretary of defense for research and development. A. J. Goodpaster, "Memorandum of Conference with the President," October 8, 1957, 2, Dwight D. Eisenhower Presidential Library, http://www.eisenhower.archives.gov/dl/Sputnik/Sputnikdocuments.html.

7. In response to several Sputnik launches, President Eisenhower approved policy guidance that was concerned primarily with countering the potential psychological and political effects of Soviet space superiority and with using space for reconnaissance and verification purposes. Manned or unmanned space weapons were mentioned only as a distant possibility. Eisenhower approved four objectives to guide evolving U.S. policy along lines that were more cooperative than competitive: 1) devote a sufficient level of effort to developing and using U.S. space capabilities to achieve U.S. scientific, military, and political purposes and to demonstrate U.S. leadership; 2) increase international cooperation; 3) achieve agreements to assure the orderly development of national and international programs for the peaceful uses of space; and 4) use space to assist in "opening up" the Soviet bloc through intelligence and scientific cooperation. See "Preliminary U.S. Policy on Outer Space," NSC 5814/1 (August 18, 1958), in NSSP, *NSC Documents.*

8. Dwight D. Eisenhower, *Waging Peace* (Garden City, NY: Doubleday, 1965), 556; and George B. Kistiakowsky, *A Scientist at the White House* (Cambridge, MA: Harvard University Press, 1976), 334. In other settings, the Soviets did not initially distinguish between satellite and aerial overflights and denounced both as an illegal infringement on national sovereignty. See Gerald Steinberg, *Satellite Reconnaissance: The Role of Informal Bargaining* (New York: Praeger, 1983), 26–29. Steinberg asserts that Soviet threats to shoot down reconnaissance satellites were credible because they used a high-altitude surface-to-air missile to bring down the U-2, but a National Intelligence Estimate done in conjunction with NSC 5814/1 did not put much weight on this possibility. "Soviet Capabilities in Guided Missiles and Space Vehicles," National Intelligence Estimate, August 19, 1958, 9, doc. SE00218, Digital National Security Archives, http://nsarchive.chadwyck.com.

9. Within three years of Sputnik's launch, the United States had launched its first photographic reconnaissance, weather, navigation, signals intelligence, missile warning, and

called the Soviet accomplishment a grave threat to national security and a challenge even greater than Pearl Harbor, evoking images of warfare in space that resonated with public fears.[10] The administration tried to allay those fears by releasing a space primer in which the President's Science Advisory Committee explained that space was inherently better suited for collecting and transmitting information than for direct weapons applications. Even if one could develop the technology to use satellites as bombers, for example, such schemes would be "clumsy and ineffective ways of doing a job."[11]

Those technical assurances did not immediately assuage the sense of alarm stimulated by the Soviet satellites and the perceived missile gap, and Senator John Kennedy successfully appealed to that alarm in winning the 1960 presidential election. Once in office, however, the Kennedy administration quickly developed a strong interest in generating rules not only to protect those national security uses of space that it found attractive but also to prevent the Soviets from pursuing military space capabilities that the United States did not want either side to have. To preclude the political problems that would be caused by Soviet nuclear weapons perpetually orbiting overhead, the Kennedy administration orchestrated a 1963 agreement renouncing weapons of mass destruction (WMD) in space as one of the first superpower arms control accords.[12]

That initiative was elaborated by the Johnson administration to produce the 1967 OST, which remains the basic legal foundation for the regulation of space activities. As president, Lyndon Johnson was personally interested in formalizing the principle that outer space, unlike air space, should be free for access and peaceful use without the permission of other states. To secure broad agreement on the OST in the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS), the United States had to accept Brazil's proposal to precede this freedom-of-use principle with the commitment that the exploration and use of space shall be for the benefit of all countries, irrespective of their degree of economic or scientific development (art. I.1). The freedom-of-use principle is strengthened by article II's prohibition on national appropriation, echoing a post-Sputnik declaration made by then-

communications satellites, reflecting the president's emphasis on military support applications that could be given little publicity. See Bob Preston et al., *Space Weapons, Earth Wars* (Santa Monica, CA: RAND, 2002), 9.

10. Senate Committee on Armed Services, Preparedness Investigating Subcommittee, *Inquiry into Satellite and Missile Programs,* 85th Cong., 1st and 2nd sess., 1958, Committee Print, 1–3.

11. "Introduction to Outer Space" (1958), in James Killian, *Sputnik, Scientists, and Eisenhower* (Cambridge: MIT Press, 1977), 288–299. The primer was originally released by the White House on March 26, 1958.

12. For domestic political reasons, this agreement took the form of parallel U.S. and Soviet statements of intent that were formally endorsed on October 17, 1963, by UN General Assembly Resolution 1884, "Stationing Weapons of Mass Destruction in Space." See Raymond L. Garthoff, "Banning the Bomb in Outer Space," *International Security* 5, no. 3 (Winter 1980/1981): 25–40.

Senator Johnson: "We of the United States do not acknowledge that there are landlords of outer space who can presume to bargain with the nations of the Earth on the price of access to this domain."[13] The principle is qualified, however, by article IX's insistence that one country's use of space should neither interfere with other countries' current space activities nor degrade the space environment for future users, and by article VII's assignment to launching states of liability for damage to other states parties. Thus, to gain the legal right to orbit reconnaissance satellites over other countries without their permission, the United States accepted a package of provisions that together "established a fair balance between the interests and obligations of all concerned, including the countries which had as yet undertaken no space activities."[14]

The portions of the OST that specifically addressed military activities balanced the general interest in peaceful uses of space with the superpowers' particular interests in using space to help stabilize deterrence while foreclosing unattractive avenues for military competition. Arms control verification, early warning, and crisis management were generally accepted as peaceful national security space activities. Article IV turned the superpowers' 1963 declarations of intent into a legal ban on WMD in orbit and also prohibited using celestial bodies for any military purpose. The treaty said nothing about putting conventional weapons in orbit, sending ballistic missiles with nuclear warheads through space, or deploying most types of anti-satellite weapons (ASATs). Article III, however, established the requirement that all space activities be conducted in accordance with international law, including the UN Charter, thus presumptively limiting the legitimate use of force in or from space to self-defense and other operations authorized by the Security Council.[15] The vague formulation of article III leaves much leeway for space-based military support operations to enhance deterrence, but it belies claims that anything not explicitly prohibited in article IV is permitted.

The OST was supplemented by other agreements expanding on the idea that some uses of space were stabilizing while others would be destabilizing. The 1972 ABM Treaty formalized an understanding that deployment of a missile defense system by one superpower would compel the other to increase its offensive weapons to preserve deterrence, leaving both worse off than before. The treaty allowed only limited missile defense, explicitly outlawed space-based ABM systems or components, and implicitly protected the use of satellites for monitoring compliance by banning interference with so-called

13. Senate Committee on Foreign Relations, "Treaty on Outer Space, Message from the President of the United States," in *Treaty on Outer Space, Hearings before the Committee on Foreign Relations,* 90th Cong., 1st sess., March 7, 13, and April 12, 1967, 105–106.

14. Official Records of the General Assembly, 21st sess., 1st comm., Summary Records of Meetings, September 20–December 17, 1966, 427–428. On the principles outlined in the Outer Space Treaty, see Ram Jakhu, "Legal Issues Relating to the Global Public Interest in Outer Space," *Journal of Space Law,* Fall 2006, 37–55.

15. David A. Koplow, "The Law Regarding Military Uses of Outer Space" (paper, George Washington University Space Policy Institute, Washington, DC, November 13, 2002).

national technical means of verification (NTM). The 1963 Limited Test Ban Treaty (LTBT) and the 1977 Environmental Modification Convention listed space among the places where specific military activities were banned.[16] Other accords protected or promoted space-based information and communications systems that supported arms control and crisis management.[17] Multilateral agreements to rescue astronauts, to assign liability for damage caused by space objects, and to register satellites launched into space addressed inadvertent problems that might be caused by space activities.

Although ASATs were technically feasible during this period, neither superpower made a sustained effort to develop and deploy a large-scale ASAT system or space-based weapons that could hit terrestrial targets. The United States generally pursued a policy of contingent restraint—that is, it sought to signal that it would keep its own ASAT efforts at a low level so long as the Soviets did likewise, and that it was prepared to accelerate its nascent ASAT programs if the Soviets deployed space weapons.[18] The United States initially considered using nuclear-tipped missiles as ASATs but learned that the electromagnetic pulse from the explosion would damage American satellites as well as Soviet ones, making nuclear ASATs impractical for most uses.[19] When the USSR initiated tests of a nonnuclear co-orbital satellite interceptor system in 1968, the United States assessed that this primitive system did not pose an immediate threat. Because ramped-up U.S. efforts to develop nonnuclear ASATs would not have much use as a deterrent, but could stimulate the Soviets to develop a more capable anti-satellite system, the Nixon administration increased passive protection for its satellites and preserved its own rudi-

16. The LTBT prohibits nuclear explosions in any environment except underground, which is understood to include tests of nuclear-tipped anti-satellite weapons or missile defense interceptors during peacetime but not nuclear weapons used during war. Article I of the Environmental Modification Convention banned the deliberate manipulation of natural environmental processes having "widespread, long-lasting or severe effects as the means of destruction, damage, or injury to any other State Party."

17. Superpower arms control agreements routinely included provisions banning interference with NTM. The 1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War committed the superpowers to consult immediately in the event of interference with communications or early-warning satellites, while the 1971 Hot Line Modernization Agreement specified the use of Soviet Molniya and American Intelsat satellites for crisis communication and committed both sides to ensure their continuous and reliable operation.

18. See Steven Weber, *Cooperation and Discord in U.S.-Soviet Arms Control* (Princeton: Princeton University Press, 1991), 204–272; and Steven Weber and Sidney Drell, "Attempts to Regulate Military Activities in Space," in *U.S.-Soviet Security Cooperation,* ed. Alexander George et al. (New York: Oxford University Press, 1988), 373–431.

19. U.S. and Soviet high-altitude nuclear tests before the LTBT generated artificial radiation belts that damaged or destroyed satellites and persisted for an extended period of time in addition to causing problems with electronic devices on Earth. The 1962 "Starfish Prime" test burned out streetlights in Hawaii, destroyed seven satellites in seven months, and left an artificial radiation belt that lasted until the early 1970s. See Barry D. Watts, *The Military Uses of Space: A Diagnostic Assessment* (Washington, DC: Center for Strategic and Budgetary Analysis, 2001), 19.

mentary ASAT system but reduced its funding for research projects on nonnuclear ASAT technology.[20] The United States interpreted the Soviet decision to stop ASAT testing in 1971 as acceptance of reciprocal restraint in space consistent with the general spirit of détente and the underlying principles of the 1972 Strategic Arms Limitation Treaty and the ABM Treaty.

As doubts grew in both countries during the mid-1970s about the other side's commitment to détente, ASAT-related allegations resurfaced. The Soviets were accused of using lasers to temporarily blind several U.S. satellites in 1975, although the Department of Defense (DOD) subsequently concluded that a gas pipeline fire was the most likely cause.[21] In 1976 the United States deployed its first reconnaissance satellite capable of providing real-time digital imagery of Soviet military locations (the KH-11), and the Soviets resumed testing their co-orbital ASAT system.[22] The Carter administration responded to the resumed Soviet ASAT tests by adopting a two-track policy of trying simultaneously to develop a more advanced type of kinetic energy (KE) ASAT—the Miniature Homing Vehicle (MHV)[23]—and also to negotiate an

20. Weber and Drell, "Attempts to Regulate Military Activities in Space," 390–393. President Ford codified the policy to rely primarily on "international treaty obligations and political measures to foster free use of space" and on passive protective measures rather than on more offensive options in "Enhanced Survivability of Critical Space Systems," NSDM 333 (July 7, 1976), in *Presidential Decisions: NSC Documents Supplement: Newly Declassified Excerpts,* ed. R. Cargill Hall (Washington, DC: The George C. Marshall Institute, 2006) (hereinafter referred to as NSSP*, NSC Documents Supplement*), 5.

21. In his first stint as defense secretary, Donald Rumsfeld told reporters the Pentagon had no evidence to support claims that U.S. satellites had been blinded by Soviet lasers. DOD provided background material attributing the satellite problems to a gas pipeline fire. Another possible explanation was that the Soviets were using lasers to track U.S. satellites, something that the United States had been doing for years. When a group of American scientists and arms control experts were able to visit the Soviet laser ranging facility alleged to have been involved, they assessed the technical characteristics of the site as posing no ASAT threat. See Phillip J. Klass, "Anti-satellite Laser Use Suspected," *Aviation Week and Space Technology,* December 8, 1975, 12; "DOD Continues Satellite Blinding Investigation," *Aviation Week and Space Technology,* January 5, 1976, 18; and "A Visit to Sary Shagan and Kyshtym," *Science and Global Security* 1, nos. 1–2 (1989): 12.

22. After reviewing numerous theories about Soviet motives for resumed ASAT testing, Paul Stares assessed that countering U.S. military capabilities was the most likely motive but noted that press reports indicating that the United States was going to embark on a new ASAT program also might have played a role. Other experts placed more weight on internal technological motivations than action-reaction dynamics. See Paul Stares, *Space Weapons and U.S. Strategy: Origins and Development* (London: Croom Helm, 1985), 146–155; and Herbert York, *Making Weapons: Talking Peace* (New York: Basic Books, 1987), 275.

23. The Soviet co-orbital ASAT system involved launching a missile when the target satellite was over the launch site, then maneuvering the interceptor close to the target before detonating and destroying the target with shrapnel fragments. Although the system was eventually declared to be operational, its test record had more failures than successes, it would be effective only against satellites in relatively low orbits, and it required significant time to launch and maneuver into position. The proposed U.S. ASAT system, by contrast, used an air-launch missile that would ascend directly to the target and destroy or disrupt it by force of impact, so the time between decision, launch, and impact would be greatly reduced. See Laura Grego, "A History of Anti-Satellite Weapons Programs," Union of Concerned

ASAT ban.[24] Some parts of the administration viewed the MHV program as a bargaining chip, while others questioned the wisdom of strategic restraint in space now that the Soviets also had numerous military support satellites.[25]

The Reagan administration laid the foundation for current U.S. space policy by emphasizing the relevance of space for warfighting over its role in stabilizing deterrence, by ending any serious pursuit of mutual ASAT restraint, and by intensifying U.S. efforts to acquire both offensive and defensive space weapons, most notably the Strategic Defense Initiative (SDI).[26] The administration's National Space Policy directed the DOD to develop and deploy an operational ASAT capability "at the earliest practical date," both to deter threats to U.S. and allied space systems and, within the limits of international law, to deny hostile military forces the use of space-based support. The policy also gave DOD its first so-called space force application mission: to prepare, consistent with treaty obligations, "to acquire and deploy space weapons systems for strategic defense should national security conditions dictate."[27] The Reagan administration tried to reinterpret the ABM Treaty's prohibition on space-based missile defenses to apply only to technologies that were in existence when the treaty was negotiated, not to "exotic technologies" such as the potential space-based lasers envisioned for SDI.[28] The Reagan administration

Scientists, 2006, http://www.ucsusa.org/global_security/space_weapons/a-history-of-asat-programs.html.

24. The Carter administration's two-track ASAT decision is laid out in "Arms Control for Anti-Satellite (ASAT) Systems," PD/NSC-33 (March 10, 1978), 153, in NSSP, *NSC Documents;* and "National Space Policy," PD/NSC 37 (May 11, 1978), sec. 2.D, 6, in NSPP, *NSC Documents Supplement.*

25. Ashton Carter, "Satellites and Anti-Satellites: The Limits of the Possible," *International Security* 10, no. 4 (Spring 1986): 46–98.

26. The Reagan National Space Policy was established in NSDD 42 (July 4, 1982) and revised in NSDD 293 (January 5, 1988). A declassified version of NSDD 42 is available in the NSSP collection and an unclassified summary of NSDD 239 is available at http://www.hq.nasa.gov/office/pao/History/policy88.htm. NSDD 42 includes a basic principle stating that the United States will study specific arms control options that might serve national security but will "oppose arms control concepts or legal regimes that seek general prohibitions on the military or intelligence use of space," but this principle is not in NSDD 293.

27. These quotes are from the unclassified summary of NSDD 293. The corresponding section of NSDD 42 is redacted in the declassified version, so it is not known whether the same language was used in the initial version of the Reagan National Space Policy.

28. The central articles of the ABM Treaty prohibit testing, development, or deployment of any ABM system except at each side's two (later one) declared land-based ABM sites. Agreed Statement D specifies that to ensure fulfillment of this general obligation, in the event of new technologies, the parties will consult about additional specific limits that might be needed. Proponents of the "broad" interpretation used Agreed Statement D in isolation to argue that the parties were free to develop and deploy ABM systems based on "other physical principles" unless additional limits were added to the ABM Treaty, but this interpretation is contradicted by the negotiating history, the ratification record, and subsequent practice by the two parties prior to the Reagan administration's unilateral reinterpretation. The controversy is reviewed in Matthew Bunn, *Foundation for the Future: The ABM Treaty and National Security* (Washington, DC: The Arms Control Association, 1990), 58–73; and Peter L. Hays, "United States Military Space: Into the Twenty-First Century," INSS

also conducted several tests of the MHV system, including one against an aging U.S. weather satellite in 1985.[29] But even at the height of renewed superpower tensions, neither side used its rudimentary capabilities to attack its adversary's satellites.

The mix of formal agreements and informal restraint created an environment in which space could be used by a growing number of countries for many purposes, and the United States played an active role in promoting some emerging civilian applications. The United States organized the first global satellite telecommunications consortium, the International Telecommunications Satellite Organization (Intelsat), in 1964, to underscore U.S. interest in peaceful, widely beneficial uses of space. The initial interim arrangement was heavily dominated by the U.S. Comsat Corporation, but the definitive arrangement negotiated in 1973 shared managerial responsibilities and procurement contracts more equitably among members with relevant capabilities and greatly expanded the availability of satellite communications to developing countries.[30] By then, France, China, and Japan could build and launch basic scientific satellites, while France and Germany had built an experimental communications satellite.[31] Technology originally developed for military purposes also became available for civilian and commercial use. The United States launched the first civilian remote sensing satellite (Landsat) in 1972, making low-resolution multispectral data available at low cost, and by the end of the next decade France and the USSR were selling higher-resolution imagery. President Reagan made signals from the U.S. military's fledgling Global Positioning System (GPS) available to commercial aircraft in 1983 after Korean Airlines flight 007 was shot down when it strayed over Soviet territory.

Each development demonstrating the practical utility and political benefits of space activities increased other major countries' desire for independent

Occasional Paper no. 42, USAF Institute for National Security Studies, 2002, 77–79, http://www.usafa.af.mil/df/inss/OCP/OCP42.pdf.

29. Congress viewed such destructive tests as provocative after the Soviets had voluntarily ceased their ASAT tests, and it voted to withhold funding unless the Soviets resumed their testing program. There were also major concerns about the projected cost of the F-15 ASAT program, which had risen from $500 million at the outset of the program to $5.3 billion by 1985. See Dwayne Day, "Blunt Arrows: the Limited Utility of ASATs," *The Space Review* (June 6, 2005), http://www.thespacereview.com/article/388/1.

30. In the years before Intelsat was formed, overseas telephone calls were rapidly increasing but still had to be carried by expensive underwater cables or unreliable shortwave radio. The Soviet bloc chose not to participate in Intelsat and instead organized their own small satellite communications organization, Intersputnik, in 1972. On the governance of Intelsat, see William J. Drake, "Communications," in *Managing Global Issues,* ed. P. J. Simmons and Chantal de Jonge Oudraat (Washington, DC: Carnegie Endowment for International Peace, 2001), 35–36.

31. The United States helped its allies' early space programs but often on terms that the partners found onerous. For example, France convinced other European countries to support the development of an independent launch capability (the Ariane program) after the United States insisted that it would launch the Franco-German communications satellites only if they were not used to compete with Intelsat.

capabilities and stimulated commercial interest. India and Israel launched their first satellites in 1980 and 1988 respectively; Arianespace, a European consortium, began launches in 1979; and the U.S. space shuttle—the first reusable launch vehicle, intended to dramatically reduce launch costs and facilitate commercial access to space—started operations in 1981.

As more countries acquired space capabilities and concerns, they tried to elaborate and extend the general principles in the OST. The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (or Moon Treaty) applied the new "common heritage of mankind" principle to all celestial bodies except the Earth. The treaty mandated that an international regime to govern the exploitation of natural resources should be established just before such exploitation became feasible, and it specified that this regime should give special consideration both to the contributions of space-farers who made such exploitation possible and to the needs of less developed countries.[32] The International Telecommunications Union, the organization that allocates orbital slots and radio-frequency spectrum, prohibited interference with nonmilitary communications in its 1982 update to the International Telecommunications Convention (the Nairobi Convention). Discussion of rules for remote sensing began after the United States started to make Landsat imagery available and culminated twelve years later after France launched the first Satellite Pour l'Observation de la Terre (SPOT) satellite. The 1986 UN General Assembly adopted a set of Principles on Remote Sensing that reaffirmed the right to collect satellite imagery without the permission of the sensed state but specified that primary and processed data should be made available to the sensed state on a timely and nondiscriminatory basis and at a reasonable cost.[33] Throughout this sequence the United States used its dominant position to gain agreement on rules that served its own military, political, and economic interests while benefiting other countries as well.

The principles, legal obligations, and informal restraints built around the OST worked reasonably well when the superpowers had most of the space capabilities, when deterrence stability was the main strategic objective, and when the state of technology limited military satellites to passive support rather than warfighting applications. As the number of space-faring countries grew and the uses of space expanded, however, efforts to elaborate the OST principles failed to keep pace. The process of rule formation stagnated during the second half of the Cold War. Few immediate problems arose because the total amount of nonmilitary space activity was limited and the superpowers' military space capabilities remained within the understanding of "peaceful"

32. As of December 2007, only thirteen countries, not including any space-faring states, have ratified the Moon Treaty, partly due to concerns about the "common heritage of mankind" language and partly due to the fact that large-scale exploitation of space resources is still not economically or technically feasible. Treaty status is at http://www.unoosa.org/oosa/SpaceLaw/moon.html.

33. UN General Assembly, *Principles Relating to Remote Sensing of the Earth from Space,* UN General Assembly Resolution A/RES/41/65, 1986, http://www.un.org/documents/ga/res/41/a41r065.htm.

uses as ones that stabilized deterrence.[34] Stagnation of the rule-making process nonetheless laid the groundwork for future difficulty as these conditions changed.

THE GROWTH OF GLOBAL COMMERCIAL INTERESTS

The underdeveloped rules for space security became a more pressing problem as rapid advances in information technology made space a more valuable arena and as space technology spread beyond the Cold War powers and their allies to developing countries and commercial firms. By the early 1990s, basic trends led many observers to predict that global commercial activities would soon replace national military programs as the dominant feature shaping space security. Although these predictions eventually proved to be overly optimistic, they played an important role in shaping policy debates and decisions about space security in the 1990s.

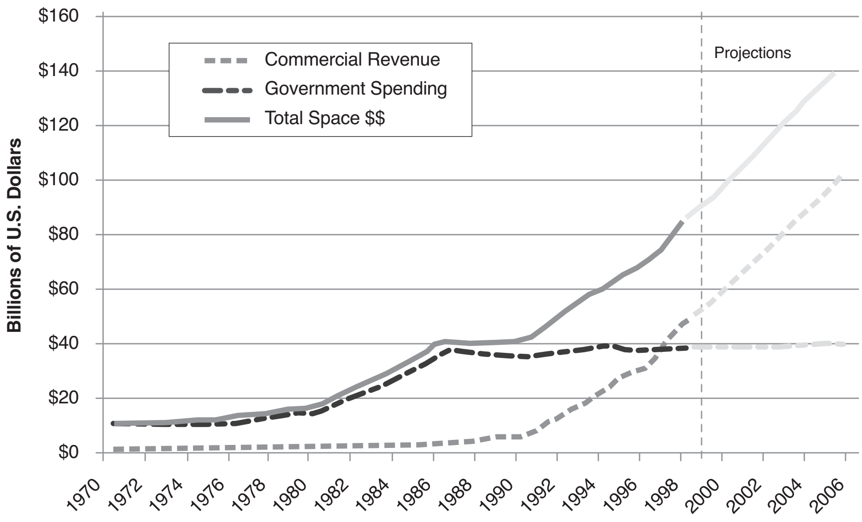
American and Russian firms with space expertise began looking for new business opportunities after the end of the Cold War and severe cutbacks in the Soviet space program removed the competitive rationale for the high levels of government spending on missile defense and space weapons research initiated during the Reagan years. Exponential advances in computing capabilities to handle large amounts of data generated optimistic forecasts for broadband communications satellites in geostationary orbit (GEO), while improvements in miniaturization and lightweight composite materials made constellations of small satellites in low earth orbit (LEO) look like a safe and cost-effective way to provide mobile telephone services.[35] As the global economy became increasingly interconnected and knowledge-driven, commercial demand for remote imagery, precision timing and navigation signals, and satellite launch services was also expected to surge. Annual global commercial space revenues, which had inched up to $6 billion by 1990, surpassed government spending on space in 1997, and were projected to reach $100 billion by 2005, while government spending was expected to stay flat (Figure 1).

Whereas space development and infrastructure costs historically had been borne by governments, industry began to invest a significant amount of private capital in developing new space technologies. Iridium, an off-shoot of Motorola, anticipated that business travelers would be willing to pay hand-

34. In 1980, for example, 105 out of 109 orbital launches were by the United States or the Soviet Union and no recognizable commercial launch industry existed. See Futron Corporation, *The Declining U.S. Role in the Commercial Launch Industry* (Bethesda, MD: Futron Corporation, 2005), 1, http://www.futron.com/pdf/resource_center/white_papers/US_Commercial_Launch_Industry_White_Paper.pdf.

35. When the first LEO-based mobile phone systems were being planned in the late 1980s, proponents thought that cellular systems would be practical only in a few high-density urban areas and that signals from mobile phones could not reach GEO satellites unless the wattage was increased so high that it would damage human ear tissue. See Alan MacCormack and Kerry Herman, "The Rise and Fall of Iridium," Harvard Business School Case no. 9-601-040, rev. November 8, 2001.

Figure 1: Projections for Commercial Space Industry Surpassing Government Spending



Source: Futron, *Satellite Industry Guide, 1999–2000* (October 1999): 1, 11.

somely for mobile phones that would work anywhere in the world. The company raised billions of dollars in private financing and overcame a number of technical and manufacturing challenges to mass produce and launch a constellation of 66 satellites over a two-year period—an unprecedented feat because satellites and launch rockets typically were custom built and mated, a process that normally took several years.[36] The Orbital Sciences Corporation offered another example of industry innovation when it used off-the-shelf and relatively inexpensive subsystems and software to develop a way to launch small satellites from aircraft rather than from dedicated sites on the ground.[37] Industry analysts anticipated a virtuous cycle in which commercial firms using private funds for space projects would be highly motivated to reduce their costs, improve their products, and protect their investments, thus making space an increasingly attractive venue for additional commercial ventures.[38]

36. Instead of building each satellite from scratch, Iridium designed its satellites and subsystems as modules and used other lean manufacturing techniques to work on five satellites at a time and assemble each in less than a week. See MacCormack and Herman, "The Rise and Fall of Iridium," 3–8.

37. The development costs for the Pegasus rocket were quite low compared to the expense of government-run projects to develop new launchers, but the per-kilogram cost for a Pegasus launch still remains high compared with other launch options. See John R. London III, "Reducing Launch Cost," in *Reducing Space Mission Costs,* ed. James R. Wertz and Wiley J. Larson (Torrance, CA: Microcosm Press; Dordrecht, The Netherlands: Kluwer Publishers, 1996), 148.

38. Because satellites are extremely expensive pieces of equipment that travel through space beyond the jurisdiction of any individual state, satellite manufacturers, financiers, and operators have been particularly interested in having uniform international legal rules to protect their investments. The UN Institute for the Unification of Private Law (UNIDROIT)

In anticipation of this projected trend, the U.S. government changed a number of space-related rules to encourage global commercial activity. After the 1986 Space Shuttle Challenger accident, the Reagan administration stopped using the shuttle for commercial payloads. To increase the number of launch options available for U.S. commercial satellites, the Reagan, George H. W. Bush, and Clinton administrations negotiated bilateral agreements with China (1988), Russia (1993), and the Ukraine (1996) to provide launch services at rates that would not be too far below those offered by U.S. firms trying to get back into the commercial launch business.[39] To facilitate overseas satellite sales, presidents Bush and Clinton transferred responsibility for communications satellite export control decisions from the State Department, which regulates foreign sales of munitions, to the more business-friendly Department of Commerce, which regulates foreign sales of dual-use goods.[40] In 1994, Presidential Decision Directive 23 authorized private firms to begin selling high-resolution satellites and imagery so that U.S. companies could compete with Russian, French, and future foreign firms for an annual satellite imagery market that was predicted to reach between $2 billion and $20 billion by 2000.[41] The United States and Russia also agreed to cooperate on the International Space Station (ISS), partly to keep Russia from selling some rocket technology to India and partly so that Russian expertise in extended human space flight could reduce the cost of a U.S. project that was in danger of cancellation.[42] The 1995 formation of Sea Launch—

is developing a draft protocol on space property that will do for space vehicles what the 2001 Convention on International Interests in Mobile Equipment, also developed by UNIDROIT, does for trains, aircraft, and other high-value mobile equipment regularly moving across national frontiers in the ordinary course of business. (The convention went into effect in 2004 and is available at http://www.unidroit.org/english/conventions/mobile-equipment/main.htm.)

39. Roger D. Lanius, "Between a Rocket and a Hard Place," in *Space Policy in the 21st Century,* ed. W. Henry Lambright (Baltimore: John Hopkins University Press, 2003), 25–26.

40. The State Department retained jurisdiction over satellite-related technology and technology for space-launch vehicles and continued to treat them as munitions rather than commercial goods.

41. Imagery, turnkey satellites, and technology sales required licenses and involved conditions such as allowing the government to exercise "shutter control" to protect national security, international obligations, or U.S. foreign policy. See Vipin Gupta, "New Satellite Images for Sale," *International Security* 20, no. 1 (Summer 1995): 94–125; and Kevin O'Connell and Beth E. Lachman, "From Space Imagery to Information: Commercial Remote Sensing Market Factors and Trends," in *Commercial Observation Satellites,* ed. John C. Baker et al. (Santa Monica, CA: RAND, 2001), 68–69. These optimistic assumptions were based on the removal of Cold War security barriers; the size of the overall remote sensing market ($1.7 billion); the assumption that satellite imagery could both capture a larger share of this existing market and draw in new users; the early success of SPOT Image (annual revenue growth of 42 percent); and technological advances in acquiring, storing, and processing data, including the availability of powerful desktop computers, the Internet for data delivery, and easy-to-use geographic information system software.

42. Susan Eisenhower, *Partners in Space: U.S.-Russian Cooperation after the Cold War* (Washington, DC: The Eisenhower Institute, 2004), 21–45.

a joint venture among Boeing, the Russian and Ukrainian makers of the relatively inexpensive and highly reliable Zenit rocket, and a Norwegian shipping firm—marked the first entirely private effort to manufacture and launch satellites and symbolized the financial advantages of global space cooperation.

In arguing for rule changes to facilitate commercial space activities, proponents did not claim that the economic benefits outweighed the negative effects on national security. Rather, they suggested that the end of the Cold War and the effects of globalization fundamentally altered security calculations so that some types of cooperation could serve both objectives. If the primary nuclear threat to U.S. security was proliferation rather than Soviet aggression, then both economic and security benefits would flow from cooperative space projects that used former Soviet military equipment and scientists for peaceful purposes and that strengthened Russia's nonproliferation capabilities and commitments.[43] If most death and destruction was now caused by civil conflict, humanitarian crises, or environmental catastrophes rather than massive cross-border aggression, then making commercial satellite imagery readily available to all interested states, as well as to intergovernmental bodies and NGOs, would increase transparency and facilitate equitable management of security problems that no one country could handle on its own.[44] If a number of other countries and private companies were now willing to sell advanced satellites, launch services, and space-based information products, then the United States would be hurting itself economically for no national security gain if it kept tight export controls on items that could be indigenously produced or acquired elsewhere in the global marketplace. Finally, if U.S. firms had a dominant position in a rapidly expanding commercial space industry, many future military needs could be met through competitively priced commercial services, per-satellite launch costs could be reduced by spreading fixed costs over more users, and companies could invest more of their own revenue in researching and developing new products rather than expecting the government to pay a large share of research-and-development costs.[45]

43. The heads of NASA during the first Bush administration recognized the scientific and economic benefits of human spaceflight cooperation with the Russians because the Russians had experience keeping cosmonauts on the *Mir* station for extended periods of time, their *Soyuz* spacecraft could be a rescue vehicle, and they were willing to provide a technologically sophisticated docking system for a fraction of the price quoted by American contractors. Still, political obstacles to Russian participation in the ISS prevented extensive cooperation until the Clinton administration persuaded Russia to forego a $400 million sale of cryogenic engine technology to India in return for a $400 million space cooperation deal with the United States.

44. Yahya A. Dehqanzada and Ann M. Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World* (Washington, DC: Carnegie Endowment for International Peace, 2000); and John C. Baker, Kevin M. O'Connell, and Ray A Williamson, eds., *Commercial Observation Satellites* (Santa Monica, CA: RAND, 2001).

45. On the mutually reinforcing benefits of U.S. dominance in global commercial, civilian, and military uses of space, see John Pike, "American Control of Outer Space in the Third Millennium" (e-print, Federation of American Scientists, November 1998), http://www.fas.org/spp/eprint/space9811.htm.

Despite these emerging considerations, traditional security concerns still impeded some space-related commerce and cooperation, such as early efforts to end the deliberate degradation of GPS signals.[46] By the time the full GPS system became operational in 1995, the number of nonmilitary GPS users had already surpassed military users because GPS receivers had become inexpensive and easy to use alone or in combination with satellite imagery, wireless communications, the Internet, and sophisticated desktop computer software. In hopes of preventing its enemies from using free GPS signals to get accurate location information, the United States was degrading the open signal while giving its own military users an encryption key to eliminate the distortion. A 1995 National Academy of Sciences' study found that this "selective availability" (SA) policy imposed burdens on legitimate GPS users without enhancing U.S. security because commercially available differential GPS technology could correct for the distortions. The study suggested that removing SA would eliminate the expense of differential GPS for commercial and civilian users, encourage more effective and widespread use of GPS technology, reduce incentives to use undegraded signals from Russia's version of GPS, the Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS), and protect GPS's position as the international standard for global satellite navigation systems.[47] A RAND study done at the same time placed more emphasis on military concerns that turning off SA during peacetime would make it politically difficult to restore SA during wartime and that turning off SA would encourage the faster spread of GPS technologies to potential adversaries, thus reducing the advantage enjoyed by the U.S. military.[48] The Clinton administration decided to continue the SA policy until 2000—by which time the U.S. military was more adept at jamming GPS signals over a localized area. This delay strengthened European resolve to develop their own precision timing and navigation system, Galileo, in order to avoid dependence on the U.S. military for a service that seemed increasingly vital to economic development and human security. As expected, ending GPS signal degradation gave a huge

46. GPS satellites broadcast two types of signals, the Standard Positioning Service (SPS or C/A-code) for general use and the Precision Positioning Service (PPS or Y-code) for military use. The United States began using SA in 1990 to deliberately degrade the location accuracy of SPS signals from 20 meters to 100 meters while giving military users encryption keys to eliminate the effects of SA. Differential GPS uses information from a reference station at a known location to compute correction factors that can be used to compensate for the effects of SA at other nearby locations. For an overview of GPS technology and policy in the 1990s, see Per Enge and Pratap Misra, "Introduction: Special Issue on Global Positioning System," *Proceedings of the IEEE,* 87, no. 1 (January 1999): 10, http://ieeexplore.ieee.org/iel4/5/15872/00736338.pdf.

47. Aeronautics and Space Engineering Board and the National Research Council, *The Global Positioning System: A Shared National Asset* (Washington, DC: National Academy Press, 1995), http://www.nap.edu/catalog.php?record_id=4920.

48. Scott Pace et al., *The Global Positioning System: Assessing National Policies* (Santa Monica, CA: RAND, 1995), 23. Commercial pressure to turn off SA during peacetime arose after it was temporarily turned off so that U.S. forces could use commercial GPS receivers during the Persian Gulf War and the 1994 intervention in Haiti.

boost to commercial use, and the ratio of nonmilitary to military users quickly reached 100 to 1.[49]

Impressive growth in commercial space activity during the 1990s led to predictions that the world was entering a "second space age" that would be shaped more by market forces and a "merchant" culture than by large-scale government projects undertaken by members of the "guardian" culture for national prestige and deterrence stability.[50] In the late 1990s, though, neither group was clearly dominant: indeed, many Clinton-era space policy debates reflected these different communities' conflicting ideas about managing the global spread of dual-use technologies. The increasing number of space users had little experience working across commercial, civilian, and military lines within their own country, let alone negotiating with merchants and guardians from other countries that now had a direct stake in issues such as the allocation of orbital slots and radio-frequency spectrum or the use of satellite imagery in crisis situations.

Failure to agree on new operating rules became increasingly problematic under the emerging circumstances. A 1995 National Research Council report warned that orbital debris posed a growing threat to individual satellites and might make entire orbits unusable unless all space-faring nations quickly agreed on debris reduction measures and data exchanges.[51] Many observers expected the case for more inclusive and effective governance of space as a "global commons" to become ever more compelling as the value of space-based communications, imagery, weather forecasting, and navigation services surged and space played an integral, if invisible, role in many other information-age activities, such as operating electrical power grids and validating credit-card transactions.

But as these optimistic predictions were peaking, developments that invalidated them were already underway. The information technology bubble burst in the late 1990s, and projected demand for broadband and other satellite communications services—the major source of profit in space—failed to materialize after exuberant investors chasing those projections had developed communications satellite constellations and fiber-optic landlines well in excess of actual market demand.[52] A similar story of disappointed expecta-

49. David Braunschvig, Richard L. Garwin, and Jeremy C. Marwell, "Space Diplomacy," *Foreign Affairs,* July/August 2003, 156.

50. Scott Pace, "Merchants and Guardians: Balancing U.S. Interests in Space Commerce," in *Merchants and Guardians: Balancing U.S. Interests in Space Commerce,* ed. John M. Logsdon and Russell J. Acker (Washington, DC: Space Policy Institute, George Washington University, 1999), 5–65.

51. The most pressing concern was that some orbits in LEO might already have reached their "critical density" of active satellites and debris, raising the possibility of a cascade in which high-velocity collisions generated new fragments faster than they were being removed by atmospheric drag, thus steadily increasing collision risk even if no new objects were added to that orbit. See Committee on Space Debris, National Research Council, *Orbital Debris: A Technical Assessment* (Washington, DC: The National Academies of Sciences, 1995).

52. Demand for communications bandwidth has grown steadily, but the carrying capacity of fiber-optic cables has grown even faster. In the 1980s, satellites provided ten times the

tions occurred in the satellite imagery field.[53] Demand for satellites and launch services also precipitously dropped just as new providers entered the international market.[54] Major losses were incurred, investors were chastened, and a large amount of unutilized communications and launch capacity discouraged new initiatives. Recently, the strongest growth in the commercial space industry has come from direct-to-home television, video, and radio services provided by entertainment companies that neither think of themselves as part of the commercial space industry nor pay attention to space security policy.[55] With private investors compelled by market circumstance to be much more cautious, government contracts have determined research and development choices. A number of high-profile satellite start-up firms—the merchants who were once expected to reshape space culture—either went out of business or, as in the case of the Iridium LEO satellite communications system, ended commercial service and went to work for the military. For some indefinite period of time, the U.S. military will remain the principal source of investment in developing new space capabilities even as international commercial utilization of those capabilities creates broader constituencies.

COMPETING CONCEPTIONS OF MILITARY USE

Within the U.S. military planning system, which sets policy directing space investment, reactions to the expansion of space utilization in the 1990s were mixed. Some saw it as an opportunity, others as a threat. William Owens,

telecommunications capacity at one-tenth the cost of submarine cables, then the only long-distance telephone alternative, but by 2003 a single fiber-optic cable could handle the total commercial satellite broadband capacity available that year. See MacCormack and Herman, "The Rise and Fall of Iridium," 3; and Captain David C. Hardesty, "Space-Based Weapons: Long-Term Strategic Implications and Alternatives," *Naval War College Review* 58, no. 2 (Spring 2005): 58.

53. The availability of inexpensive satellite imagery failed to stimulate vast new demands at a time when the advent of GPS technology was making it easier and cheaper to satisfy existing local imagery needs with aerial surveys. Instead of reaching $2–$20 billion by 2000 as projected, commercial remote sensing revenue that year was only $173 million. See O'Connell and Lachman, "From Space Imagery to Information," 70.

54. By 2001, ten-year forecasts for commercial satellite launch demand had dropped from the 1997 high-growth forecast of 85 payload launches per year to 45 payload launches per year, and even those projections proved overly optimistic. See the series of annual reports released by the Federal Aviation Administration, Office of Commercial Space Transportation and the Commercial Space Transportation Advisory Committee, *Commercial Space Transportation Forecasts,* http://www.faa.gov/library/reports/commercial_space/forecasts/.

55. Even that sector has not done as well as initially expected. In its June 2006 *State of the Satellite Industry Report,* the Satellite Industry Association (SIA) lowered its previous estimates of annual global revenue from direct broadcast services, with its estimate for 2004 dropping 39 percent from $49.5 billion to $35.8 billion. Because direct broadcast satellites account for a major portion of worldwide commercial satellite revenues, the SIA estimate for total 2004 satellite industry revenues also dropped significantly, from $97.2 billion to $82.7 billion.

who served as vice chairman of the Joint Chiefs of Staff (JCS) during the boom in commercial expectation, believed the projected expansion of space-based information capabilities would allow the United States to increase its security with lower budgets, fewer troops, and less risk. Speaking in his official capacity, Owens proposed building future U.S. military capabilities around an integrated "system of systems" in three domains with close links to space—intelligence, surveillance, and reconnaissance (ISR); command, control, communications, computers, and intelligence; and precision-guided munitions.[56] The tactical value of space information had been demonstrated during the 1991 Persian Gulf War, when U.S. troops used handheld GPS receivers—including 15,000 commercial devices—to coordinate troop movements over large areas of featureless desert, enabling a surprise flanking maneuver around Iraqi forces in Kuwait.[57] Owens anticipated that advances in digitization and computer processing would allow satellite imagery to be delivered directly to users in the field rather than having lengthy delays while satellites were tasked and images downloaded to ground stations, then transferred via film or fax to analysts and decision makers. That emerging capability would provide superior "situational awareness" across a wide range of security contingencies from humanitarian assistance, through peace operations, to high-intensity conflict.

In "The Emerging System of Systems," Owens urged the United States to match its military capabilities to political objectives for reshaping the security environment. After retiring from the military, Owens elaborated his strategic concept in an article with Joseph Nye, a civilian architect of the Clinton administration's defense policy.[58] They argued that the United States currently had an advantage in information collection, processing, and dissemination capabilities, partly due to Cold War investments and partly to the vibrancy of the commercial information technology sector in an open society. Because information technologies were dispersed throughout the global economy, other countries might try to match or challenge U.S. superiority in space-based military support systems unless these capabilities were used for political purposes that had broad international support. Owens and Nye argued, though, that nobody else would spend enough money to engage in competitive development of military space technology if the United States shared its situational awareness for mutual benefit and avoided using its information edge in ways that threatened others.[59] They also urged the United States to

56. Adm. William A. Owens, "The Emerging System of Systems," *Military Review* 75, no. 3 (May/June 1995): 15–19.

57. Watts, *Military Uses of Space,* 41–42.

58. Joseph S. Nye and William A. Owens, "America's Information Edge," *Foreign Affairs,* March/April 1996, 20–36.

59. France and Israel had recently deployed the world's first nonsuperpower reconnaissance satellites in large part because they could not count on receiving imagery from the United States and felt that access to information had been used to manipulate their security policies. France had disliked having the United States be the sole source for imagery used by the allies during the Persian Gulf War. Indeed, President Chirac remarked that without

use its information advantage not only to deter or defeat traditional military threats but as a "force multiplier" for diplomatic responses to emerging security problems. They concluded that "if a state can make its power legitimate in the perception of others and establish international institutions that encourage them to channel or limit their activities, it may not need to expend as many of its costly traditional economic or military resources."[60]

In *Joint Vision 2010,* a collective planning document issued in 1996, the U.S. military services accepted the idea of leveraging information technology to reduce the "fog and friction of war" so that U.S. and allied troops could achieve results with "less need to mass forces physically than in the past." That document did not mention the broader cooperative security concept that Owens and Nye had advanced, but it did keep space-based military assets in a supporting role for ground, air, and maritime forces, with only one oblique reference to "space forces" and another to "battlespace control operations to guarantee the air, sea, space, and information superiority that is needed to gain the degree of control to accomplish the assigned tasks." [61]

Six months after *Joint Vision 2010* was released, however, the U.S. Space Command (SPACECOM) issued its own *Vision for 2020,* depicting the global expansion of space utilization as a threat rather than an opportunity and advancing a stark conception of national military space power.[62] Gone was any idea of sharing space-based information for mutual protection or using U.S. dominance in information technology to promote U.S. interests through cooperation rather than coercion. Instead, SPACECOM claimed that a competitive "gold rush" was occurring in space, with the number of satellites likely to double or triple over the next five years, and depicted space as a lawless frontier like the nineteenth-century American Wild West.[63] SPACECOM also asserted that war in space was inevitable because the "space 'playing field' is leveling rapidly" and satellites are vulnerable, high-value targets;[64] it urged

indigenous satellite capabilities, Europe would be little more than a "vassal" of the United States. Israel's decision had been made earlier, after the United States would not or could not provide imagery to Israel before the 1973 Yom Kippur War, and then fluctuated between denying and supplying subsequent imagery requests. Israel's first reconnaissance satellite was launched in 1995. Since then, several other space-faring countries, including Japan, India, and Pakistan, have decided to launch their own reconnaissance satellites for similar reasons. See Jeffrey T. Richelson, "The Whole World Is Watching," *Bulletin of the Atomic Scientists* 62, no. 1 (January/February 2006): 26–35.

60. Nye and Owens, "America's Information Edge," 36.

61. John M. Shalikashvili, *Joint Vision 2010* (Washington, DC: Joint Staff, 1996), 13, 18, 20, 23, http://www.dtic.mil/jv2010/jv2010.pdf.

62. United States Space Command, *Vision for 2020* (1997), http://www.fas.org/spp/military/docops/usspac/visbook.pdf.

63. Theresa Foley, "Space: 20 Years Out," *Air Force Magazine Online* 83, no. 2 (February 2000): 2, http://www.afa.org/magazine/feb2000/0200space.asp. Foley quotes SPACECOM Commander General Richard B. Meyers.

64. United States Space Command, *Long Range Plan Implementing USSPACECOM Vision for 2020* (1998), ch. 1, 1, http://www.fas.org/spp/military/docops/usspac/lrp/toc.htm.

the U.S. military to utilize space not merely to support deterrence but also to enhance terrestrial warfighting missions and to develop the capacity for combat in space itself.

Vision for 2020 argued that the United States could maintain "full spectrum dominance" only if it had offensive and defensive "control of space"—that is, the ability to access and use space freely for its own purposes, to protect its own space assets, and to deny the use of space to others when necessary. *Vision for 2020* advocated a unilateral form of "global engagement" that combined space-based observation with the ability to apply "precision force from, to, and through space," and it promoted the concept of "full force integration," envisaging the "same level of joint operations between space and the other mediums of war-fighting as land, sea, and air currently enjoy today."

Vision for 2020 and the subsequent *Long-range Plan Implementing USSPACECOM Vision for 2020* are the foundational documents for the current effort to achieve decisive U.S. military space dominance, a program that would overturn the historical legacy of strategic accommodation and legal regulation and that would indefinitely subordinate commercial development to the exercise of military power in space. The term *SPACECOM* can thus serve as a shorthand for the community of people within and outside the U.S. military who believe that the United States should try to maximize its military power in space and who emphasize preparations for space warfare over legal and diplomatic efforts to protect space assets. Within this community exist important variations—for example, in one early typology that still remains useful, David Lupton contrasted what he called the "space sanctuary" doctrine with three other military space doctrines: "survivability" (anti-satellite weapons needed to deter attacks on vulnerable satellites), "space control" (ensure that the United States can freely use space to support terrestrial operations but hostile militaries cannot), and "high ground" (space will be the decisive theater of combat because of its utility for missile defense and/or global strike weapons).[65] Yet, neither the *Vision for 2020* nor subsequent doctrine, planning, and policy documents indicate which version of space power doctrine is being endorsed, so the term *SPACECOM* should be understood as a general analytical device rather than a reference to a specific document, theory, or organizational entity.[66]

65. See David E. Lupton, *On Space Warfare* (Maxwell Air Force Base, AL: Air University Press, 1988); and the updated version in Hays, "United States Military Space," 6–8.

66. When *Vision for 2020* was written, the Air Force, Army, and Navy each had their own space commands, all separate from U.S. Space Command. In 2002, U.S. Space Command merged with U.S. Strategic Command under the STRATCOM name, and the Navy Space Command merged with the Naval Networks Operation Command. The Air Force Space Command is now the organizational entity within the military that has the lead on many acquisition and operational programs related to the SPACECOM vision, but some of the most vocal proponents are at military schools or think tanks.

Vision for 2020 went far beyond the prevailing political consensus. As the text acknowledged, "the notion of weapons in space is not consistent with U.S. national policy."[67] SPACECOM's supporters in Congress complained that most of DOD still viewed space "as an information medium to support existing air, land, and sea forces, rather than the strategic high ground from which to project power."[68] The commercial sector remained focused on opportunity rather than conflict of any sort. Satellite communications firms in particular dismissed offers of military protection because they did not believe alleged threats were real, doubted that space weapons would make them safer, and thought that countries gaining space capabilities were more likely to become investment partners than attackers.[69] Nonetheless, the SPACECOM vision was as much a political program as a strategic conception, with dedicated missionaries able to command and sustain more attention than military planning documents usually enjoy.

The Clinton administration did not attempt to resolve the conflict of purpose posed by the legacy of strategic restraint, the projections of commercialization, and the vision of U.S. military dominance. The unclassified version of its 1996 National Space Policy used ambiguous language to finesse contradictions among those who primarily wanted to develop military support services, those who wanted to promote commercialization, and those who wanted to pursue decisive space dominance. The policy did not set priorities among civilian, commercial, military, and intelligence uses of space; it directed DOD to "maintain the capability to execute the mission areas of space support, force enhancement, space control, and force application" but did not elaborate as to what capabilities these missions involved or how vigorously they should be pursued; it also paired military space control language retained from Reagan/Bush space policy directives with language reiterating the value of normative or legal restraint, but it did not specify the relative importance of rules and force for protecting U.S. space assets:

> Consistent with treaty obligations, the United States will develop, operate and maintain space control capabilities to ensure freedom of action in space and, if directed, deny such freedom of action to adversaries. These capabilities may also be enhanced by diplomatic, legal or military measures to preclude an adversary's hostile use of space systems and services.[70]

The most visible political struggle over space security during the 1990s involved missile defense, a central component of the SPACECOM vision, with

67. United States Space Command, *Long Range Plan,* 12.

68. *National Defense Authorization Act for Fiscal Year 2000,* 106th Cong., 1st sess., 1999, S. Rep. 50, 346. See also Colin S. Gray and John B. Sheldon, "Space Power and the Revolution in Military Affairs," *Aerospace Power Journal,* Fall 1999, 23–38.

69. Pace, "Merchants and Guardians," 47–48.

70. White House, National Science and Technology Council, "Fact Sheet: National Space Policy," September 19, 1996, 5, http://history.nasa.gov/appf2.pdf.

the Republican-controlled Congress pressing for fast and full deployment and the White House favoring an incremental approach designed to preserve the ABM Treaty. In October 1997, the Clinton administration permitted the initial test of the ground-based Mid-infrared Advanced Chemical Laser against a dying Air Force satellite and justified the test as a defensive experiment to assess vulnerability. That same month, though, President Clinton used his line-item veto to thwart congressional efforts to fund space-based missile defense research (billed as asteroid defense), a military space plane, and an ASAT program that had been terminated in 1993.[71] Congressional Republicans then mandated a commission chaired by Donald Rumsfeld to recommend steps to strengthen national security space policy. The commission report luridly warned of a "Pearl Harbor" in space—again evoking the surprise attack image Johnson had used some four decades earlier—and it vigorously endorsed changes to the National Space Policy in line with the SPACECOM vision. The report attempted to establish presumptions that would justify the pursuit of dominance—the inevitability of conflict in space and the imperative of securing decisive national advantage before any potential enemy could do so—and to impose the burden of proof on anyone who would question those presumptions.[72]

Skirmishes also occurred over satellite export control policy. In 1998, members of Congress who assessed trade with China in terms of strategic advantage used charges of Chinese nuclear espionage and access to sensitive information during investigations of satellite launch failure to return commercial communications satellites to the State Department's munitions control list and to impose new restrictions on the transfer of missile-related technology.[73] DOD intensified its satellite export monitoring program, and Congress imposed additional notification requirements. These moves added complexity, uncertainty, arbitrariness, and delay to the satellite export control process.[74] They were depicted as essential to ensure that potential enemies

71. The funding was included in the FY1998 defense appropriations bill.

72. That this is an advocacy report, not a balanced assessment of the benefits, costs, and risks of different approaches to space security, is underscored by the commission's decision to compare the "opportunity costs of the status quo versus the advantages of making changes to better attain U.S. interests in space." Commission to Assess United States National Security Space Management and Organization (hereinafter referred to as the Rumsfeld Commission), *Report of the Commission to Assess United States National Security Space Management and Organization,* 2001, 6, http://www.globalsecurity.org/space/library/report/2001/nssmo/index.html.

73. U.S. domestic politics, especially congressional efforts to impeach President Clinton, created an environment in which it was nearly impossible to reach agreement on a reasonable balance between trade benefits and security risks in the new export control rules. See Robert D. Lamb, "Satellites, Security, and Scandal: Understanding the Politics of Export Control," CISSM working paper, Center for International and Security Studies at Maryland, College Park, MD, January 2005, http://www.cissm.umd.edu/papers/files/lamb_export controls.pdf.

74. For a more detailed description of the export control process and its effects, see Joan Johnson-Freese, "Alice in Licenseland: U.S. Satellite Export Controls since 1990," *Space Policy,* August 2000, 195–204; and Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007), 140–169.

did not learn anything that might improve their military satellites or ballistic missiles, but they had the practical effect of ending all U.S. commercial satellite activities with China and placing severe restrictions on Sea Launch, the ISS, and other U.S-Russian collaborations.[75]

The election of George W. Bush in 2000 brought staunch SPACECOM supporters into key policy positions. Rumsfeld became secretary of defense, and other participants in his space commission became top civilian appointees in the Pentagon. General Richard Myers, recently SPACECOM commander, was appointed chair of the JCS, thereby quieting, although not eliminating, resistance from those in the military who judged space weapon development to be a waste of money and a potential danger to space-based military support systems.[76] The new appointees immediately proceeded to pursue the SPACECOM vision. Under their authority the United States withdrew from the ABM Treaty, ordered the deployment of a limited ground-based missile defense system, and expanded the development budget for a broad assortment of new military space capabilities.

The Bush administration took those actions in a manner that implicitly acknowledged that neither the technical capability nor the broad political consensus necessary to implement the vision had actually been achieved. The missile defense installations said to be deployed were exempted from development test requirements designed to demonstrate effectiveness, and informed assessments around the world generally doubt their actual capabilities. The administration did not issue its own space development plan for nearly six years. The National Space Policy finally released in October 2006 was framed by the adversarial outlook of the Rumsfeld Commission's *Report* and the various SPACECOM planning documents, but it tried to project continuity by recycling vague language from the Clinton space policy document to describe the kinds of military space capabilities that the United States would develop.[77] Because the Bush administration has generally been hostile to the Clinton legacy, the implication of the decision to use the Clinton National Space Policy for so long is that they are afraid to say clearly and authoritative-

75. Space cooperation with Russia has also been affected by the Iran Nonproliferation Act of 2000, which prevents U.S. payments to Russia in connection with the ISS unless the U.S. president determines that Russia is taking steps to prevent the proliferation of missile and other technology to Iran.

76. Although the loudest advocates for space weapons are in the Air Force Space Command, the rest of the Air Force leadership is generally not supportive. Dwayne Day summarized the reasons for their skepticism by noting that most space weapon proposals "do not abide by the laws of physics, few of them abide by the laws of bureaucratic and international affairs, and none of them abide by the laws of fiscal reality." Dwayne Day "General Power vs. Chicken Little," *The Space Review,* May 23, 2005, 5, http://www.thespace review.com/article/379/1.

77. Although the document was signed by President Bush on August 31, 2006, the unclassified summary was not made public until 5 p.m. on October 6, 2006, the Friday before Columbus Day weekend. White House Office of Science and Technology Policy (OSTP), "U.S. National Space Policy," August 31, 2006.

ly what pursuing the SPACECOM vision actually entails and how much of this project they have endorsed. The idea of space weapons is unpopular with the American public, and even the dedicated advocates are cautious about exposing their plans and programs to close scrutiny.[78]

The political ascendance of SPACECOM supporters has been coupled with a corresponding decline in the commercial space industry as an independent actor influencing U.S. space policy. Although the Bush presidential campaign pledged to make the U.S. export control process more rational and less restrictive, administration officials have zealously applied the tightened export restrictions and pursued costly legal actions against top U.S. satellite firms accused of violations. The commercial interests affected largely conceded the greater impediments imposed after discreet lobbying efforts to modify them proved ineffective. Industry executives have long been eager to avoid any allegation of pursuing profit to the detriment of national security, and that traditional deference was strengthened when assessments of commercial opportunity in space became more circumspect.

Partly as a result of the administration's zeal and industry's deference, the U.S. share of the commercial space market has substantially declined.[79] A single satellite sale requires an average of nine separate licenses and four months of bureaucratic deliberation to secure necessary approval, and the outcome of any application is not assured even for transactions involving close allies.[80] In response to chronic delays and uncertainties, traditional U.S. customers such as Arabsat, Telsat Canada, and Intelsat have begun to chose "ITAR-free" satellites from European suppliers—that is, ones that do not entangle them in U.S. export control regulation. U.S. firms have stopped bidding for contracts that might be problematic, such as a Korean satellite for military and civilian communications or any satellite for China. China has purchased six communications satellites from Europe and Israel and has begun selling an indigenous communications satellite to other developing countries.[81] The U.S.

78. When asked various questions about competitive versus cooperative approaches to space security, overwhelming majorities of Americans consistently preferred strategic restraint. See Steven Kull, John Steinbruner, Nancy Gallagher, Clay Ramsay, and Evan Lewis, *Americans and Russians on Space Weapons* (College Park, MD: Program on International Policy Attitudes and Center for International and Security Studies at Maryland, 2007), http://www.worldpublicopinion.org/pipa/pdf/jan08/CISSM_Space_Jan08_rpt.pdf.

79. For a more general discussion of the effects that export control are having not only on the U.S. commercial space industry but also on space research at U.S. universities, the ISS, and the Moon/Mars initiative announced by President Bush in January 2004, see George Abbey and Neal Lane, *U.S. Space Policy: Challenges and Opportunities* (Cambridge, MA: American Academy of Arts and Sciences, 2005), http://www.amacad.org/publications/spacePolicy.pdf.

80. James A. Lewis, *Preserving America's Strength in Satellite Technology: A Report of the CSIS Satellite Commission* (Washington, DC: Center for Strategic and International Studies, 2002), 21.

81. Ryan Zelnio, "The Effects of Export Control on the Space Industry," *The Space Review,* January 16, 2006, http://www.thespacereview.com/article/533/1.

share of global satellite manufacturing and launch revenues decreased from 60 percent in 1997 to 40 percent by 2006.[82] The value of these contracts lost primarily due to ITAR regulations is estimated at between $2.5 and $6 billion dollars.[83] Of the three leading firms in the U.S. space industry, Loral declared bankruptcy in 2003, and Boeing and Lockheed Martin decided to focus on U.S. government business rather than global commercial sales. An industrial base for eventual commercial expansion still exists in the United States and presumably would respond to unmistakably compelling opportunity, but its internal impulse has been sharply constrained, and its once dominant competitive advantage is being progressively diminished.

The public discussion accompanying these developments has been limited and has not as yet penetrated to the fundamental issues involved. The assertion of inevitable threat has been repeatedly proclaimed and occasionally reported along with what are said to be indicative incidents, but mitigating details have generally been omitted. One of the most persistent jamming problems was diplomatically resolved after it was determined that the Libyan jammers were trying to interfere with satellite phones used by smugglers and might not have understood that they were disrupting service to legitimate satellite phone users outside of Libya.[84] References to Iraqi interference with U.S. satellite-based navigation systems during the 2003 invasion of Iraq rarely mentioned that Iraqi forces jammed U.S. military GPS receivers, not satellite signals, or that the jammers were destroyed without space weapons. Repeated assertions that a Chinese microsatellite is being developed for "parasitic" or "killer" purposes are based on a single independent and unsubstantiated source in China.[85] China's January 2007 test of a direct-ascent ASAT against an aging weather satellite is the most recent incident to be used as evidence that "the threat to our space security is real and growing."[86] This test

82. Futron Corporation, *"State of the Satellite Industry" Report,* June 2007, 15–16. The average U.S. share of the global satellite communications market has dropped even more sharply from 83 percent to 50 percent since the export control changes.

83. The export control process has also imposed other costs on U.S. firms, including lost revenue in the satellite launch sector, $70,000 per day penalties for late satellite deliveries, and $46 million in fines for alleged export control violations. See Zelnio, "The Effects of Export Control on the Space Industry."

84. Peter de Selding, "Libya Pinpointed as Source of Months-Long Satellite Jamming in 2006," *Space News,* April 9, 2007, http://www.space.com/spacenews/businessmonday_070409.html.

85. Jeffrey Lewis, "Programs to Watch," *Arms Control Today* 34, no. 9 (November 2004): 12; and Jeffrey Lewis, "False Alarm on Foreign Capabilities," *Arms Control Today* 34, no. 9 (November 2004): 14–17.

86. The Chinese government has said little about the test other than that "the experiment was not directed at any country nor did it pose a threat to any country." SPACECOM supporters moved quickly to depict the test as a reason for the Bush administration to redouble efforts to achieve military space dominance, while proponents of cooperative security in space have used the test to underscore the need for new rules, especially about debris-generating ASATs. The best effort to date by Western analysts to understand why China conducted the test emphasizes technological and bureaucratic factors rather than a deliberate

showed the world that China now also has a capability that the United States demonstrated two decades ago, but the purpose of the Chinese program is no more clearly offensive or defensive than is the intent behind the more advanced U.S. ASAT development programs.[87] The distinct possibility that pursuit of the SPACECOM vision would stimulate or exacerbate threats beyond those that would otherwise occur is rarely if ever acknowledged when inevitability is asserted.[88]

Similarly, facile analogies to more familiar environments are often used to increase comfort with the concept of space control. British control of the high seas is periodically cited to support the contention that the United States must rely on force rather than law to protect its freedom of access, but those who have advanced that argument have not been required to discuss either the differences between the space and ocean environments or the fact that ocean law has evolved since the mid-nineteenth century toward a progressively more codified and comprehensive legal regime.[89] Similar appeals to "seize the high ground of space" ignore the technical fact that orbiting weapons would not offer significant and lasting advantages over less expen-

effort either to threaten U.S. satellites or to spur negotiations. See Gregory Kulacki and Jeffrey Lewis, "Understanding China's ASAT Test" (unpublished ms., 2007).

87. Another recent set of allegations about Chinese ASAT development had noteworthy parallels to claims about Russian lasers used in the late 1970s to increase support for U.S. ASAT work. During the final stages of congressional debate on the FY2007 defense authorization bill, which includes funding for U.S. military space programs, a *Defense News* article quoted several unnamed officials and experts who claimed that China had tested ground-based lasers against U.S. spy satellites. No substantiating evidence was offered, nor were enough details given to know whether any laser test that did occur was intended to "blind" electro-optical satellites or was for more benign purposes, such as satellite tracking. The article noted that White House officials who would be in a position to know the classified details decided not to include the strong form of these allegations in a recent DOD report on China's military capabilities, which contains only one sentence noting that China has a powerful laser that could be used to interfere with U.S. reconnaissance satellites. When questioned about the allegation, the director of the National Reconnaissance Office confirmed that at least one U.S. satellite had been illuminated but not damaged by a Chinese laser. The top U.S. military officer in charge of space also stated that the United States had no clear evidence that China had intentionally disrupted U.S. satellite capabilities. See Vago Muradian, "China Attempted to Blind U.S. Satellites with Lasers," *Defense News,* September 25, 2006; Warren Fester and Colin Clark, "NRO Confirms Chinese Laser Test Illuminated U.S. Spacecraft," *Space News,* October 2, 2006; and Elaine Grossman, "Top Commander: Chinese Interference with U.S. Satellites Uncertain," *Inside the Pentagon,* October 12, 2006.

88. For a fuller critique of the inevitability argument, see Karl P. Mueller, "Totem and Taboo: Depolarizing the Space Weapons Debate," in *Space Weapons: Are They Needed?* ed. John M. Logsdon and Gordon Adams (Washington, DC: George Washington University Space Policy Institute, 2003), 18–26.

89. The U.S. military strongly supports the Law of the Sea Convention because it sees worldwide acceptance of the treaty as a more efficient and reliable way to ensure freedom of navigation than bilateral agreements, customary law, or coercive power would be. See Nina Tannenwald, "Law versus Power on the High Frontier: The Case for a Rule-Based Regime for Outer Space," *The Yale Journal of International Law* 29, no. 2 (Summer 2004): 363–422.

sive and less vulnerable terrestrial alternatives for most military missions.[90] While much of the current U.S. military advantage does come from using space-based information and communications assets more extensively than anyone else, that does not necessarily mean that a competition for military control of space is the most effective and efficient way to protect those assets and to minimize the chance of other states using similar capabilities for hostile purposes. In general in the American public discussion, tolerance for the expression of political attitude has not been accompanied by basic standards for substantive assessment.

After a half century of experience the original principle of strategic accommodation in space is in jeopardy. The legal instruments and operating rules that embody that principle have so far prevented any major dispute over space activity. But formal efforts to elaborate those rules have been blocked, primarily by an unresolved conflict between competing conceptions in the United States. As a result, the legacy regime remains incomplete and has been unable to adapt either to increasing commercial utilization or to the growing sophistication and consequence of military uses, especially by the United States. The consequences are not immediate, but they eventually could become serious. With intense advocates promoting a radical vision that will predictably be objectionable to most of the world, well-informed and broadly representative judgment must be brought to bear, and the full array of interests at stake must be examined with greater care than has yet occurred.

90. Orbiting satellites provide a high vantage point from which one can see, communicate with, or attack a large swath of Earth, but unlike a hill or some other lofty terrain in contested territory, more than one country can use space for a high vantage point at the same time. A satellite gains no defensive advantage from being high: its visibility and predictable movement make it an easier target. Hurling weapons down from high altitudes also conveys no offensive advantage—instead of using gravity to lessen the energy costs of weapon delivery, a substantial amount of extra energy is needed to de-orbit a weapon and send it back to Earth. See David Wright, Laura Grego, and Lisbeth Gronlund, *The Physics of Space Security* (Cambridge, MA: The American Academy of Arts and Sciences, 2005), 11. On the relative merits of space-based weapons and other ways of performing the same military mission, see Bruce M. DeBlois, Richard L. Garwin, R. Scott Kemp, and Jeremy C. Marwell, "Space Weapons: Crossing the Rubicon," *International Security* 29, no. 2 (Fall 2004): 50–84; William L. Spacey II, "Assessing the Military Utility of Space-Based Weapons," *Astropolitics* 1, no. 3 (2003): 1–43, and Michael O'Hanlon, *Neither Star Wars nor Sanctuary* (Washington, DC: Brookings, 2004).

The Question of Feasibility

A logical first step in the process of examination is to consider the ultimate feasibility of the concept of military space dominance. If the original judgment about space operations is wrong and decisive dominance is possible, then significant questions of equity assuredly will be posed. If space cannot be physically controlled as originally assumed, then the vision is ultimately doomed to fail, and comparably significant questions arise about the consequences of pursuing that vision. The contending perspectives have conflicting assessments of feasibility that are not likely to be resolved until the fundamental issues are themselves resolved. And because the leading edge of technical accomplishment is obscured by security classification, even the most detached public assessment is subject to some uncertainty. The question of feasibility, however, is largely a matter of relative cost—in particular the price of acquiring the capability to control access to space as compared to the price of denying that capability. Likewise evident is that the proponents of dominance should in principle be asked to carry the burden of proof—that is, to demonstrate that dominance could be acquired at tolerable cost. The natural and apparently compelling presumption is otherwise.

That presumption can reasonably be reversed, however, if the capability in question is not supreme mastery of space but rather a superior ability to use space for forceful intrusion on Earth. Exercising absolute space dominance would depend on the ability to prevent the successful insertion into Earth orbit of any unauthorized object or the unauthorized use of any space asset while assuring orbital access and subsequent operation for those that are authorized. Categorical control of that sort has not been possible up to this point and, as realized from the outset of the space age, is inherently unlikely for technical reasons. Support for highly intrusive military missions is already well advanced, however, with apparently substantial scope for improvement in the ability to identify specific targets and to attack them as they are observed.

No current or imminent capability to attack targets from space exists, and, as also originally realized, such capability remains unlikely for technical reasons. Nonetheless, observation, communications, and navigation services from space are integral to the emerging ability to conduct precise, finely timed intrusive missions, and a substantially enhanced capacity to undertake such missions is a likely result of pursuing the SPACECOM vision even if absolute dominance cannot be achieved. To the extent that intrusive capability is developed and displayed, dominance will predictably be contested.

Informed international reactions are likely to be driven by judgments about how far and how fast the United States is moving toward acquiring absolute space dominance or intolerably intrusive space superiority. The Air Force Space Command (AFSPC) *Strategic Master Plan FY 06 and Beyond,* which builds on previous SPACECOM planning documents, provides a basic guide for making those judgments. The plan identifies major missions; assesses current capabilities; and sets near-, medium-, and far-term steps to becoming a "full spectrum space combat command" by 2030.[91] The analysis includes some AFSPC responsibilities that are not space-specific, such as land-based nuclear missiles, and excludes national security space projects outside of AFSPC's responsibility. Tracking the progress of efforts to achieve specific types of space capabilities is also complicated by frequent reconfiguration of development efforts, including name changes, shifts in mission emphasis, and cancellation of one program followed by the birth of a new program designed to accomplish similar objectives. In general, though, as adapted in table 1, the *Strategic Master Plan* specifies the capabilities that SPACECOM considers necessary to achieve effective dominance and provides a baseline for assessing actual accomplishments to date.

Table 1: SPACECOM mission areas

Mission Areas	Function	Examples
Force Enhancement	support warfighter in air, land, sea, and space operations	photoreconnaissance, electronic eavesdropping, communications, GPS, weather
Force Application	weapons operating from space against terrestrial targets	space-based global strike weapons ("Rods from God," space-based laser, space plane with CAV)
Space Control or Counterspace	protect U.S. space assets, neutralize adversary capabilities, provide space situational awareness	space surveillance network, passive defenses (hardening, etc.), active defenses (e.g., guardian satellites), anti-satellite weapons (destructive and nondestructive), space-based missile defense interceptors
Space Support and Mission Support	satellite launch and control, underlying infrastructure	launch vehicles, launch facilities, satellite control networks, training facilities, security forces, installations

91. See Air Force Space Command, *Strategic Master Plan FY06 and Beyond,* 2003, 2, http://cdi.org/news/space-security/afspc-strategic-master-plan-06-beyond.pdf.

Force enhancement: From SPACECOM's perspective, satellites are invaluable because of "their ultimate 'high ground' access, their ability to rapidly forward deploy with minimal logistics tail, and their relative immunity from threats."[92] SPACECOM wants to modernize current capabilities to provide more precise and comprehensive information, faster and more securely, in a manner that is integrated into a single network-centric system-of-systems rather than the current mission-unique, stove-piped approach. In the area of satellite communications, DOD plans include launching a number of Advanced Extremely High Frequency satellites to replenish its current Military Strategic and Tactical Relay (MILSTAR) secure communications satellites with a constellation that can provide more capacity and speed, then replacing that system with the Transformational Satellite Communications System (TSAT), an ultra-large bandwidth secure communications system that would use lasers to rapidly move information to and from friendly forces operating in even the most remote locations.[93] To address emerging challenges such as rogue states, terrorists armed with WMD, or other small-scale threats that are difficult to identify and destroy, the Air Force transformation plans include a space radar that can see moving targets even at night or in cloudy weather and a hyperspectral imaging system that can detect chemical, biological, radiological, nuclear, and high explosive materials.[94] The National Reconnaissance Office (NRO), which builds and manages spy satellites, also has several ambitious and expensive programs, including efforts to deploy a larger constellation of smaller, lighter satellites with radar and electro-optical imagery capabilities to provide more valuable data, on a more frequent schedule, in forms that can easily be integrated with other intelligence information.[95] The most ambitious SPACECOM supporters depict these future satellites as the key to having an "unblinking eye" that can be used to find and target any potential threat to U.S. security, allowing them "to know something about everything at all times" and to be able to "switch on the spotlight" to get detailed information if the "illuminator" revealed a potential problem.[96]

92. AFSPC, *Strategic Master Plan,* 36.

93. The TSAT under development by DOD involves five satellites that communicate using lasers and jam-proof radios; it promises to provide extremely fast and secure voice, video, and data transmissions worldwide, such that images that today might take nearly an hour to send could be transmitted in less than a second. See Michael Fabey, "Firms Offer Interim Satcom Gear as U.S. TSAT Moves Ahead," *Defense News,* January 9, 2006, 14.

94. The promised result from these transformation systems is continuous predictive battlespace awareness (as compared with the present-day capacity for near-real-time battlespace information), defined as "multidimensional understanding . . . in time, space, and effect, regardless of the adversary, weather, location, or time of day." Air Force, "Counterspace Operations," Air Force Doctrine Document 2-2.1, August 2, 2004, 24, http://www.dtic.mil/doctrine/jel/service_pubs/afdd2_2_1.pdf.

95. This was originally called the Future Imagery Architecture (FIA) program and is described in John Pike, "Future Imagery Architecture," http://www.globalsecurity.org/intell/systems/fia.htm.

96. Noah Shachtman, "Feds Want All-Seeing Eye in Sky," *Wired,* October 17, 2003, http://www.wired.com/politics/law/news/2003/10/60855. Shachtman quotes Stephen

Force Application: SPACECOM argues that addressing emerging threats requires a prompt, nonnuclear global strike capability offering "precise and selective lethality" to be used "when time is absolutely critical, risks associated with other options are too high, or when no other courses of action are available."[97] SPACECOM's *Long Range Plan* proposed that by 2020 the U.S. military should be able to hold at risk 100 percent of fixed, relocatable, and moving high-value targets and to deliver precision-guided weapons anywhere in the world within ninety minutes of launch.[98] Global strike capabilities could be provided by mass-to-target weapons, most notoriously the "rods from God" idea of mimicking asteroids by stationing Earth-penetrating rods on satellites in LEO, then deorbiting them so that they would fall rapidly to Earth and destroy the designated target. The global strike capabilities could also come from directed-energy weapons, such as space-based lasers or radio-frequency energy weapons.[99] A third approach, officially called FALCON (for Force Application and Launch from Continental United States) but often referred to as a "space bomber," involves developing a reusable space plane that could be launched on demand and travel above national airspace until it reached the target country (thus obviating the need for overflight permission and avoiding air defenses). The craft would release a (proposed) "common aero vehicle" (CAV) that could selectively strike a wide range of difficult targets, including mobile vehicles, deeply buried bunkers, and aircraft in flight.[100] If a CAV-armed military space plane was deployed in orbit, proponents claim that it could strike targets within moments of combat identification and "ensure our ability to kill future terrorists if we know where they are."[101]

Space control: Proposals for space control capabilities are motivated by the desire to perpetuate the tremendous asymmetrical advantages that the U.S.

Cambone, then undersecretary of defense for intelligence, speaking at the 2003 Geo-Intel Conference. Although Cambone acknowledged the utility of various sources of intelligence information, he emphasized the value of radar satellites for imagery collection around the clock and in any weather.

97. AFSPC, *Strategic Master Plan,* 27.

98. United States Space Command, *Long Range Plan,* Chapter 6, p. 18.

99. "Hypervelocity Rod Bundles," the Evolutionary Air and Space Global Laser Engagement concept, and space-based radio frequency weapons for use against electronics and national command and control systems are described on D-7, D-5, and D-10, respectively, in Appendix D, U.S. Air Force, *2003 Transformation Flight Plan* (November 2003), http://www.af.mil/library/posture/AF_TRANS_FLIGHT_PLAN-2003.pdf. The 2004 version of the flight plan, which came out only months after the 2003 version, removed all references to these specific weapon concepts.

100. FALCON is a Defense Advanced Research Projects Agency/Air Force program that has undergone various name and rationale changes since Congress barred work on a weaponized CAV in 2004 but that still exists as part of DOD's effort to develop long-range strike options. It is related to, but not the same as, the Falcon family of launch vehicles being developed by the SpaceX Corporation.

101. ONE TEAM, "The Military Space Plane: Providing Transformational and Responsive Precise Global Striking Power," January 2002, 13, http://www.wslfweb.org/docs/msp/military_spaceplace_utility.pdf.

military currently gains from space systems by defending friendly space assets "anywhere and anytime on or above the globe" and preventing an adversary's hostile use of its own space assets or commercial services by the same expansive criteria.[102] Space situational awareness is the prerequisite for all other space control activities. This includes continuous and systematic surveillance to identify and track all friendly, hostile, and neutral satellites, as well as any space debris that might interfere with U.S. space operations. Space situational awareness also includes environmental monitoring to forecast natural hazards such as solar flares; on-board systems or inspector satellites to evaluate satellite anomalies and determine whether they were caused by a natural hazard, an internal malfunction, a piece of debris, or a deliberate attack; and damage assessment capabilities to determine if action against a target satellite has had the desired effect.

SPACECOM wants full-spectrum defensive and offensive counterspace capabilities. This involves some innocuous measures, such as camouflage, hardening satellites and communications links, and increasing satellite maneuverability. Guardian satellites have been proposed for active defense of U.S. satellites.[103] Desired offensive anti-satellite capabilities include some nondestructive techniques, such as deception, jamming communications or navigation signals, and blinding satellite sensors. But they also comprise some destructive capabilities to be used if temporary or reversible options are deemed inadequate, such as attacks on ground stations and kinetic or directed energy ASATs. While SPACECOM documents indicate a preference for nonlethal over lethal effects, they want both types of capabilities.[104] SPACECOM also foresees a possible need to negate satellites that belong to neutral or friendly parties to prevent their use by hostile forces.[105] Finally, the SPACECOM vision includes missile defense systems that could target satellites in orbit more easily than ballistic missiles in flight and it emphasizes space-based missile defense interceptors that could, in theory, stop missiles (or satellites) launched from locations that sea- or air-based boost-phase interceptors could

102. AFSPC, *Strategic Master Plan,* 21.

103. The Air Force has announced plans to fly an experimental guardian satellite in 2009. Under the Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS) program, a small satellite launched into GEO near a host satellite would be able to monitor space weather conditions, detect nearby ASATs, diagnose technical problems with the host satellite, and perform other functions. See Jeremy Singer, "Space Monitor: Experimental U.S. Sat Would Patrol Region near Spacecraft," *Defense News,* November 28, 2005, 14.

104. In addition to political considerations, SPACECOM has a practical reason for preferring nondestructive space control options: debris created by a kinetic-energy ASAT could damage satellites belonging to the United States and its allies. DOD has not requested money for a KE ASAT since the early 1990s, but Congress sometimes adds funds for the Army's KE ASAT program, most recently in the FY2005 missile defense budget. The head of SPACECOM called destructive ASAT attacks a "last ditch option," both because of the debris problem and the danger of legitimating attacks on U.S. satellites. See Charles Aldinger, "General Warns: High-Tech Warfare Could Litter Space with Debris," *Reuters,* March 28, 2001, http://www.space.com/news/spaceagencies/space_war_debris_010328_wg.html.

105. Air Force, *Counterspace Operations,* 40–42.

not reach.[106] In the most ambitious version of the SPACECOM vision, this capability would enable the United States to veto any use of space that did not meet its approval.[107]

Space Support: Responsive spacelift is the most important transformation objective in this mission area. Fulfilling SPACECOM's ambitions would require dramatic reductions in launch costs without any decrease in reliability in order to have any chance of being economically feasible. Deploying enough satellites to provide all of SPACECOM's desired capabilities on schedule would also require a significant reduction in the amount of time it takes to build satellites, to mate them with launchers, and to have a turn on the launch pad. Transformational objectives also include "responsive" capabilities to launch new satellites on short notice or reconfigure satellites already in orbit to replace ones that had been attacked or to provide new capabilities tailored to a particular crisis or conflict situation.[108]

PRACTICAL IMPLEMENTATION

While the instinct of military planners to imagine futuristic weapons and other innovative capabilities that might be useful under different circumstances is both natural and desirable, such concepts usually remain fantasies unless they can be rationalized in the military planning and acquisition

106. Some SPACECOM planning documents classify space-based missile defense interceptors under force application, but our typology leaves them under space control because of their utility as anti-satellite weapons and our definition of force application as being used against terrestrial targets.

107. Everett C. Dolman, a professor at the School of Advanced Airpower Studies at Maxwell Air Force Base in Alabama, has proposed that the U.S. military should seize control of LEO, use space-based weapons to prevent any other country from deploying military assets there, and should require advanced notice of a spacecraft's civilian or commercial mission and flight plan before granting permission to launch. "The military control of low-Earth orbit would be for all practical purposes a police blockade of all current spaceports, monitoring and controlling all traffic both in and out." Everett C. Dolman, *Astropolitik* (London: Frank Cass, 2002), 157. No official SPACECOM documents have proposed such comprehensive space control, but all advocate the ability to deny space services to hostile users. When asked how to stop China from blinding most U.S. satellites in LEO during a crisis, the head of STRATCOM, General James Cartwright, told the Strategic Forces Subcommittee of the Senate Armed Services Committee that he needed "prompt global strike" to target launch facilities, missiles in flight, command and control, and other nodes in China's system. A transcript of General Cartwright's response to questions before the Strategic Forces Subcommittee on March 28, 2007 is included in U.S.-China Economic and Security Review Commission, "Statement of Dr. Michael Pillsbury," in *Hearing on China's Military Modernization and Its Impact on the U.S. and the Asia-Pacific,* March 30, 2007. http://www.uscc.gov/hearings/2007hearings/written_testimonies/07_03_29_30wrts/07_03_29_30_pillsbury_statement.php.

108. AFSPC, *Strategic Master Plan,* 29–31. On responsive lift for reconstitution of damaged satellites and the short-notice deployment of new space capabilities, see also Simon P. Worden and Randall R. Correll, "Responsive Space and Strategic Information," *Defense Horizons* 40 (April 2004): 1–8, http://www.ndu.edu/ctnsp/defense_horizons/dh40.pdf.

process as an efficient and effective response to a real threat. When the Bush administration took office, the United States faced no clear threats comparable to Cold War concerns about massive conventional or nuclear attack, especially not in space. One of Rumsfeld's early acts as secretary of defense was to shift from a threat-based planning process to a capabilities-based process in order to justify the major budget increases needed to speed military transformation and acquire expensive space capabilities. The 2001 Quadrennial Defense Review asserts that strategic uncertainty "requires the United States to focus on emerging opportunities that certain capabilities, including advanced remote sensing [and] long-range precision strike . . . can confer on the U.S. military over time."[109] In a capabilities-based process, the U.S. acquisition of advanced space systems is limited only by technology, money, and political will rather than by a balanced assessment of actual threats, opportunity costs, and unintended consequences. Therefore, it is worth asking how SPACECOM aspirations compare with accomplishments during the Bush administration and what the United States and the rest of the world might realistically expect to result if the United States continues in its pursuit of the SPACECOM vision after a change of administration.

Doctrinal and Legal Changes

Perhaps the most consequential change since the 1997 release of *Vision 2020* is that U.S. space policy no longer has stabilizing deterrence as the primary strategic objective. Nor are space activities to be guided by the political purposes that Admiral Owens had in mind when he proposed using advanced information technology to address emerging global security problems in ways that reduced the need for costly economic and military resources. The 2002 National Security Strategy fundamentally alters the context for all U.S. military uses of space by declaring that the United States will go on the offensive and "make use of every tool in our arsenal" to prevent the emergence of threats before they are fully formed.[110] The 2001 Nuclear Posture Review provides a more detailed depiction of a new approach to security based not on the traditional nuclear deterrence triad (land-, sea-, and air-strategic systems) but on a new strategic triad comprising nuclear and nonnuclear offensive strike systems, active and passive defenses, and a responsive infrastructure, bound together by enhanced command and control and intelligence systems—each component of which is intimately connected to space systems.[111]

The central role of space in this new strategy was institutionalized by merging the U.S. Space Command with the U.S. Strategic Command and

109. U.S. Department of Defense, *Quadrennial Defense Review Report,* September 30, 2001, 14, http://www.defenselink.mil/pubs/pdfs/qdr2001.pdf.

110. The National Security Strategy of the United States of America (September 2002), http:www.whitehouse.gov/nsc/nss.html.

111. The December 2001 Nuclear Posture Review is classified, but excerpts are at http://www.globalsecurity.org/wmd/library/policy/dod/npr.htm.

assigning to the expanded STRATCOM responsibility for conducting global strike, operating missile defenses, and providing comprehensive command support.[112] Some SPACECOM supporters viewed this as a step in the wrong direction because the combined responsibilities diluted the focus on space instead of making SPACECOM into a distinct and unified full-spectrum combat command.[113] But for anyone whose immediate concern is with the expanded use of space for long-range precision power projection using the full range of capabilities covered by the new strategic triad, the merger has worrisome implications.

With coercive prevention enshrined as the dominant national security strategy and long-range precision conventional strike weapons elevated to the same status as nuclear weapons in the Nuclear Posture Review, SPACECOM supporters had all the top-level cover they needed to reinterpret the vague language from the 1996 National Space Policy to fit their vision of space as a war-fighting command. The Clinton National Space Policy included a passage directing the DOD to "maintain the capability to execute the mission areas of space support, force enhancement, space control, and force application," but this was originally understood not to include the development and deployment of space weapons.[114] Bush administration military space planning documents redefined these mission areas and capabilities to include the various space weapons described above. On offensive anti-satellite weapons, the AFSPC *Strategic Master Plan* declared that national policy already required the development of "negation" capabilities and authorized their deployment "as needed to ensure freedom of access and operations in space," with a decision by the president or secretary of defense needed only to approve the actual "employment of force against enemy space assets." As for space weapons aimed at terrestrial targets, the *Strategic Master Plan* noted that conventional global strike weapons were now part of the offensive leg of the new strategic triad, asserted that "international laws and treaties do not prohibit the use or presence of conventional weapons in space," and stated that "our nation's leadership will decide whether or not to pursue the development and deployment of conventional, space-based systems for global strike to fully exploit the advantages of space."[115]

The Bush administration has taken equally decisive action to change the international legal context for its military space activities. In the same month

112. In the bureaucratic jargon of the plan, command support is referred to as "C4ISR," an acronym covering most space-based military support activities for command, control, communications, computers, intelligence, surveillance, reconnaissance, and information operations.

113. From this perspective, the merger is explained in terms of a desire to keep the total number of commands the same when NORTHCOM was established to enhance homeland defense after the September 11, 2001 attacks.

114. Theresa Hitchens, "National Space Policy: Has the U.S. Air Force Moved the Goal Posts?" (remarks at the Henry L. Stimson Center, May 20, 2004), http://www.cdi.org/program/document.cfm?DocumentID=2231&from_page=../index.cfm.

115. AFSPC, *Strategic Master Plan,* 35.

that the new National Security Strategy and the SPACECOM/STRATCOM merger were announced, the United States also withdrew from the ABM Treaty. This was not a necessary condition for taking the next logical steps in research and development but a political move to indicate the Bush administration's firm intention to deploy a large, layered defense system.[116] The administration has rejected all international efforts to consider new legal limits on missile defense or any other military space activities. For years, the United States and Israel abstained while almost every other country in the world voted for a UN General Assembly resolution in support of negotiations on an agenda item known as prevention of an arms race in outer space (PAROS), and in 2005 the United States went one step further by voting against the resolution.[117] The United States has also used procedural maneuvers in the Conference on Disarmament (CD) to prevent formal discussions, let alone negotiations, on additional legal limits on military space activities.[118] On space debris and other issues where the United States wants more international cooperation, it has backed voluntary guidelines over legal obligations in keeping with the Rumsfeld Commission's advice to "be cautious of agreements intended for one purpose that, when added to a larger web of treaties or regulations, may have the unintended consequences of restricting future activities in space."[119]

116. Philip Coyle, "The ABM Ambush," *The Washington Post,* July 13, 2001.

117. By fall 2005, John Bolton, one of Rumsfeld's closest allies in the Bush administration, had moved from being undersecretary of state for arms control and international security to ambassador to the United Nations, giving him more direct control over U.S. voting behavior. The tally for the 2005 PAROS resolution was 180-2-0. In 2006 and 2007, Israel moved back to abstaining on the resolution, leaving the United States as the only country to vote against the resolution even after Bolton had left the government.

118. In 1994 the CD reconvened an ad hoc PAROS discussion group that had been first formed in 1985 after President Reagan's announcement of the SDI sparked fears of a U.S.-Soviet space competition. After the Clinton administration began to look more serious about missile defense and NATO accidentally dropped three precision-guided bombs on the Chinese Embassy in Belgrade during Operation Allied Force, China declared in 1999 that its willingness to accept a CD work plan that included fissile material cutoff treaty (FMCT) negotiations—a U.S. priority for the CD—was contingent on a negotiating mandate for PAROS. To promote consideration of the issue in the CD, China and Russia in 2002 submitted a joint working paper on "Possible Elements for a Future International Legal Agreement in the Prevention of the Deployment of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects," but the United States continued to insist that PAROS negotiations were unnecessary because there was no arms race in outer space. No progress was possible until China reversed itself in July 2003 and accepted a discussion-only mandate for PAROS. The Bush administration then changed its position on FMCT to preclude verification while agreeing only to discuss "issues related to PAROS," a combination that was unacceptable to China and several other CD members. The United States eventually agreed to a compromise in which FMCT negotiations would begin without prejudice to the question of verification and PAROS discussions would start without precluding future negotiations, but whether this compromise will be enough to get consensus on a CD work plan in 2008 is presently unknown. See Michael Hamel-Green, "New Impetus, Old Excuses: Report on the Conference on Disarmament in 2007," *Disarmament Diplomacy* 86 (Autumn 2007), http://www.acronym.org.uk/dd/dd86/86cd.htm.

119. Rumsfeld Commission, *Report,* 17–18.

The United States has been using a permissive interpretation of the OST and the other remaining rules regulating military space activities. The traditional U.S. interpretation, shared by most other space-faring countries but not universally accepted, was that "nonaggressive" military support activities were consistent with the peaceful-use principle.[120] When Bush administration officials or SPACECOM writings mention the OST, though, they typically assert that any military uses of space that are not explicitly prohibited in article IV (WMD in orbit and military activities on celestial bodies) are permitted. That contention ignores article III's specification that space activities must be in accordance with international law, including UN Charter rules about the threat or use of force.

SPACECOM lawyers maintain that other countries' failure to object as the United States steadily expands the scope of "peaceful" military space activities indicates tacit acceptance of U.S. behavior. The AFSPC chief of space and international law asserted that "various unopposed military uses of space may as a practical matter enlarge the unofficial definition of 'peaceful purposes' to the point that specific arms control agreements may be the only effective limitation on development and deployment of various weapons in space."[121] She noted that U.S. military space activities are constrained in other ways, including the international Law of Armed Conflict (LOAC) and U.S. Armed Forces Standing Rules of Engagement (SROE). But these unilateral constraints are weakened by the controversial U.S. position that "anticipatory self-defense" is consistent with the UN Charter and by the contentious claim that the LOAC principles of discrimination and proportionality might require the use of space assets "to successfully carry out near-surgical strikes with minimum civilian casualties."[122]

Other countries have protested the expansion of U.S. military space activities. Chinese CD representatives repeatedly have said that U.S. plans run "counter to the fundamental principle of peaceful use of outer space" and have speculated that the U.S. goal in outer space is to "defy the obligations of international legal instruments and seek unilateral and absolute military and strategic superiority."[123] The United States has paid little heed to this diplo-

120. Ivan Vlasic, "The Legal Aspects of Peaceful and Non-peaceful Uses of Outer Space," in *Peaceful and Non-peaceful Uses of Space,* ed. Bhupendra Jasani (New York: Taylor and Francis, 1991), 37–55.

121. Elizabeth Waldrop, "Weaponization of Outer Space: U.S. National Policy," *High Frontier,* Winter 2005, 36–37.

122. Waldrop, "Weaponization of Outer Space," 40–41. Waldrop does acknowledge some additional practical legal restrictions on U.S. military space activities, such as the SROE requirement for specific authorization before conducting operations against foreign space-based systems and LOAC neutrality rules governing what can be done to stop belligerents from using satellite imagery or communications that belong to third parties.

123. See "Statement by H.E.[His Excellency] Mr. Li Changhe—Chinese Ambassador for Disarmament Affairs, Head of the Chinese Delegation for the Conference on Disarmament—at the Plenary Meeting of the CD," March 12, 1998, www.nti.org/db/china/engdocs/lich0398.htm; Fu Zhigang, "A Chinese View of Star Wars," *The Spokesman* 72 (c. 2000): 17–18; and "Statement by Ambassador Hu Xiaodi for Disarmament Affairs of China at the Plenary of the Conference on Disarmament," June 7, 2001, http://www.nti.org/db/china/engdocs/cd060701.htm.

matic opposition. Bush officials use the fact that the international consequences of U.S. withdrawal from the ABM treaty seemed relatively minor, at least initially, as evidence that China, Russia, and other countries currently voicing opposition to space weapons will not have much choice but to accept whatever the United States decides to do.

The most striking thing about the new U.S. National Space Policy released in October 2006 is its belligerent, nationalistic tone at a time when the Bush administration is asking China, Russia, and a number of other space-faring nations for help with proliferation crises in North Korea and Iran. The policy contains no substantive surprises for those who have been paying attention to the lower-level military space documents and diplomatic developments. The only concession to domestic and international concerns about U.S. military space ambitions is continued use in the unclassified version of vague language from the Clinton National Space Policy directing the secretary of defense to maintain capabilities to execute the four major space missions. The presidential directive does not explicitly mention anti-satellite or space-to-earth weapons, nor does it clarify whether the administration has officially embraced the "space control" version of the SPACECOM vision or the "high ground," full-spectrum combat command conception, to use Lupton's typology.

The new policy opens by framing the primary objective as relative national advantage rather than mutual benefit and by declaring that "freedom of action in space is as important to the United States as air power and sea power." The principles guiding the 2006 National Space Policy assert a broad array of U.S. rights and vital interests in space but no longer acknowledge that all other countries have the same rights and interests. For example, whereas the 1996 policy "rejects any limitations on the fundamental right of sovereign nations to acquire data from space"—a specific right established and qualified by the corresponding rights of sensed states in the 1986 Principles on Remote Sensing—the comparable 2006 language "rejects any limitations on the fundamental right *of the United States to operate in* and acquire data from space."[124] In contrast to decades of U.S. policy that considered equitable rules and reciprocal restraint as providing valuable protections for U.S. space activities, the 2006 policy emphasizes that the United States is prepared to take unilateral action to dissuade, deter, defeat, and, if necessary, deny any space-related activities that are hostile to its interests. Moreover, the 2006 policy gives the Rumsfeld Commission's anti–arms control principle presidential authority:

> The United States will oppose the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space. Proposed arms control agreements or restrictions must not impair the rights of the United States to conduct research, development, testing, and operations or other activities in space.[125]

124. White House, National Science and Technology Council, "National Space Policy"; and OSTP, "U.S. National Space Policy"; emphasis added.

125. OSTP, "U.S. National Space Policy."

The 2006 National Space Policy is the culmination of the effort initiated with *Vision for 2020* to make SPACECOM's conception of information-age space security into official U.S. policy. If foreign leaders had any doubts about President Bush's willingness to endorse SPACECOM's ambitions for military space dominance, those doubts should be dispelled now. But important questions remain about the basis in reality for this declaratory policy. As the chief foreign commentator for the conservative-leaning British newspaper of record observed:

> Space [is] no longer the final frontier but the 51st state of the United States. The new National Space Policy that President Bush has signed is comically proprietary in tone about the U.S.'s right to control access to the rest of the solar system. The document makes a serious point about our growing dependence on satellites, the military threats to them, and ways of protecting them. But America has rejected the desire by 160 other countries to have United Nations talks about banning an arms race in space, an extravagantly unilateral approach whose appeal you might have thought would have been tarnished by its experience in Iraq.[126]

Financial Investment

One way to assess how far the United States might actually go toward realizing its ambitions for military space dominance is to examine budget documents. The rapid rise in U.S. military space spending reflects a general intention to acquire as rapidly as possible the capabilities outlined in the SPACECOM planning documents, but informed observers will inquire as to which programs are absorbing the bulk of the money, how much progress the United States is actually making, and whether the projected rate of spending is likely to provide the desired capabilities on the projected schedule.

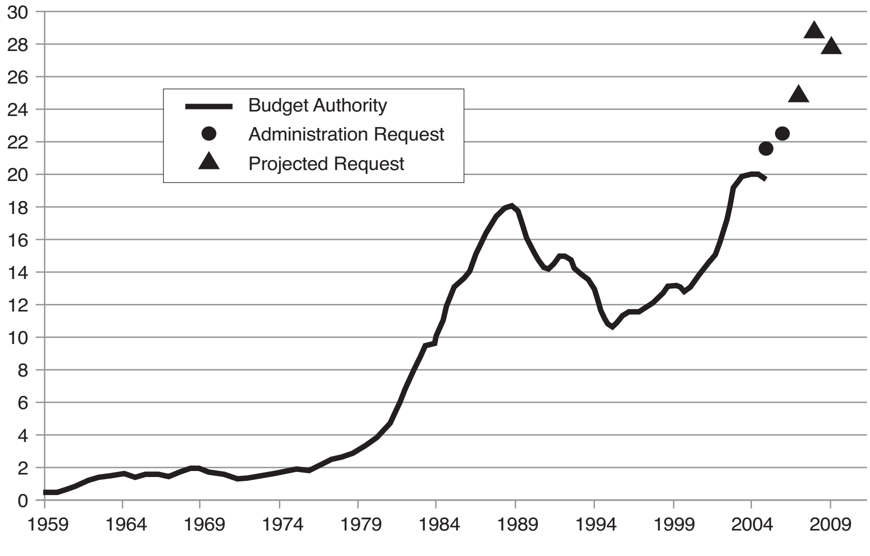
None of these questions is easy to answer because the DOD has neither a unified budget nor a consistent method of tracking military space spending. The Air Force is the lead agency for military space, but other services have their own space projects. The Missile Defense Agency (MDA), the Defense Advanced Research Projects Office (DARPA), and the NRO also have significant national security–related space budgets. The figure most commonly cited for U.S. military space spending reflects those classified and unclassified budget lines that the Pentagon has chosen to aggregate into a "virtual" Major Force Program (vMFP). This accounting device provides a rough indicator of trends over time, but it might underestimate by half the total U.S. government spending on space for national security. For example, DOD's fiscal year (FY) 2005 request for items in its space vMFP was $21.7 billion, but whether this includes budget requests for the NRO and the National Geospatial Intelligence Agency (NGA), which totaled $9.5 billion that year, is not public

126. Bronwen Maddox, "America Wants It All—Life, the Universe, and Everything," *The Times,* October 19, 2006.

knowledge.[127] Space VMFP does not include MDA spending, however, and the MDA request for FY2005 was $9 billion, an unknown portion of which was for space-related activity.[128]

Figure 2 shows the past, present, and future rate of U.S. military space spending on items in the VMFP in real-year dollars. The figures for FY1959 through FY2004 are the budget authority appropriated by Congress. FY2005 and FY2006 show both the president's request and the congressional appropriation. Projected requests for FY2007–FY2009 were provided in 2004 by DOD's Office of the Comptroller to Marcia Smith of the Congressional Research Service (CRS). Since then, DOD has become more reluctant to provide aggregate information about spending on programs in the space VMFP. DOD did not provide updated projections for the November 2005 CRS space programs report and has been unwilling since then to provide CRS with the total amount of money that the administration requested and that Congress actually appropriated for programs in the space VMFP, although information shared with allies suggests that the actual FY2008 request was close to the

Figure 2: U.S. military space spending, 1950–2009 (in billions of unadjusted dollars by fiscal year)



Source: *2004 Aeronautics and Space Report of the President,* submitted to Congress by NASA, Appendix D-1A, p. 119 and Marcia Smith, U.S. Space Programs: Civilian Military and Commercial, CRS Issue Brief #IB92011 (October 21, 2004): 8–9.

127. Some sources assume that the NRO and NGA budgets are included in the space VMFP, while others assume they are not, which might reflect the fact the space VMFP categorization has not been consistent over time. Repeated efforts to get a definitive answer from DOD or from government research offices that track the space budget have been unsuccessful.

128. On the difficulties of tracking U.S. military space spending using the VMFP figures, see Marcia Smith, "U.S. Space Programs: Civilian, Military, and Commercial," CRS Issue Brief, Congressional Research Service, Library of Congress, 2005, CRS-10; and Space Foundation, *The Space Report 2006: The Guide to Global Space Activity* (Colorado Springs, CO: Space Foundation, 2006), 73–75.

projected request for that year. Thus, efforts to understand overall patterns in U.S. military space spending currently are constrained to using data from the FY2006 request and before, although some information about individual programs can still be extracted from subsequent budget cycles.

The Bush administration's emphasis on space as a critical enabler of defense transformation and the coercive prevention strategy has been reflected in its budget priorities. The rate of increase during the current administration has been comparable to the sharp rise during the Reagan years; however, the starting point (i.e., the level of military space spending in the previous administration) was much higher in the current administration. If budget authority is adjusted for inflation, then the 2004 figure of $20 billion dollars would be comparable to military space spending in 1985 and the projected requests for 2008 and 2009 would surpass the Reagan-era peak of $25.6 billion in 1988.[129] If space-related spending in the intelligence and missile defense budgets was included in the Reagan-era calculations for DOD spending on space but is not part of the space vMFP now, then the actual rate of spending on military space activities could be approximately twice as much as it was during the Reagan years. Twenty to forty billion dollars in annual military space spending might seem small when the overall U.S. defense budget is well over six hundred billion dollars (including supplemental spending on the wars in Afghanistan and Iraq), but that amount is huge compared with the space spending of all other countries and in inflation-adjusted dollars would be at the upper limit of Congress was willing to support during the Reagan military space build-up.[130]

DOD does not identify all the budget lines included in the space vMFP, so external (and many internal) observers cannot determine precisely how the money is allocated among different types of acquisition efforts and operation of existing space capabilities. The Congressional Budget Office (CBO) analyzed the FY2006 military space spending request for $22.6 billion and identified about $7 billion that it considered funding for the development and acquisition of major unclassified space systems.[131] The CBO analysis excluded systems that are managed by the NRO, whose space systems are highly classified and whose annual budget is reportedly another $5–7 billion.[132] How

129. See Appendix D-1A (DOD spending in real-year dollars) and Appendix D-1B (DOD spending in inflation-adjusted dollars) in *Aeronautics and Space Report of the President,* 101–102.

130. The U.S. government spends at least four times more on space than all other governments combined. The disparity on military space budgets is even starker, with some analysts estimating U.S. military space spending at 95 percent of the world's total (assuming that NRO and NGA are not included in the vMFP number). Precise comparisons are impossible, though, because many countries include some dual-use programs in their civilian space budgets. See Space Foundation, *The Space Report 2006,* 75.

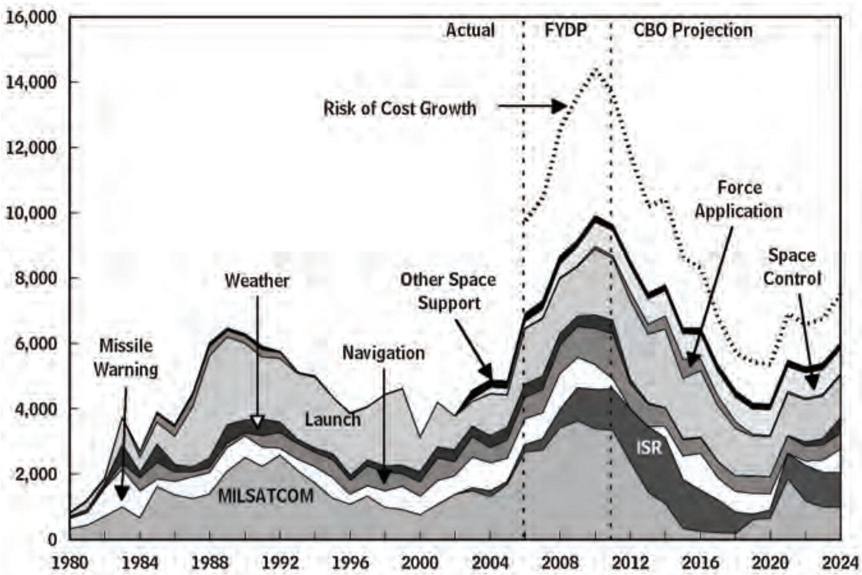
131. Congressional Budget Office (CBO), *The Long-Term Implications of Current Plans for Investment in Major Unclassified Military Space Programs,* 2005, http://www.cbo.gov/ftp docs/66xx/doc6637/09-12-militaryspace.pdf. The CBO defines unclassified space programs as those with content that is not highly classified.

132. Michael Fabey, "Spy Sats Seek Relevance in War on Terror," *Defense News* (April 3, 2006): 8.

much additional money for highly classified work is included in the VMFP is unclear, although classified military spending on space is probably rising at about the same rate as overall military space spending.[133] The rest of the money in the space VMFP is for minor development programs and for the operation and support of existing space systems.

The CBO's inflation-adjusted analysis in Figure 3 shows that the rate of investment in new military space capabilities grew faster than the overall rate of military space spending in both the Reagan years and the Bush administration, with current plans for annual investment in new space capabilities peaking well above Reagan-era figures. The FY2006 request represented a 40 percent increase over FY2005 budget authority for these programs, with investment growing from 22 percent of DOD's total space budget in 2005 to 31 percent in its FY2006 request.[134] The CBO's "risk of cost growth" line reflects the fact that research, development, testing, and evaluation costs for DOD's space systems historically have grown by 69 percent from the original development estimates, while procufrement costs have risen by an average of 19 percent.

Figure 3: U.S. Investment in Major Unclassified Military Space Programs (in millions of 2006 dollars)



Source: Congressional Budget Office based on data from the Department of Defense

Notes: FYDP = 2006 Future Years Defense Program; MILSATCOM = military satellite communications; ISR = intelligence, surveillance, and reconnaissance.

133. An analysis of three million contract and modification records from 2000 to 2004 found that the number of classified contracts mirrored the overall rise in space and satellite work for the first three years, but the classified/unclassified breakdown for 2004 was not available. Michael Fabey, "Pentagon Is Opaque about Satellite Funding," *Defense News,* February 13, 2006, 8.

134. CBO, *Long-Term Implications,* 1.

The vast majority of the $6.9 billion requested for FY2006 investment in major unclassified military space programs was for space support and force enhancement missions, not for space control or force application. Space-based communications received the largest share (approximately $2.7 billion), followed by space launch ($1.7 billion). ISR received $1 billion, including the Space-Based Infrared System (SBIRS) and space radar but excluding NRO programs. Navigation received $0.6 billion and weather received $0.4 billion. For FY2006, "other space support" totaled $0.24 billion, force application totaled $0.03 billion, and space control totaled $0.2 billion. All other unclassified military spending on space weapons fell below the CBO's threshold of significance.

Most of the money tracked in the CBO report was being spent on projects begun during the Clinton administration, including several communications upgrades, SBIRS-High, GPS improvements, and the Evolved Expendable Launch Vehicle (EELV). Current funding for the two programs that exemplify SPACECOM's transformational aspirations for the force enhancement mission, TSAT and space radar, was relatively low: Congress appropriated only $429.2 million for TSAT and $98.3 million for space radar in FY2006. The CBO report estimated, however, that these two programs could grow to consume almost one-third of all investment in major unclassified space systems and up to 5 percent of the Air Force's total investment funding if the United States continues on its current trajectory.[135]

Judging from the public record, the United States is not acquiring new space-based force enhancement capabilities and integrating them into terrestrial warfighting operations as fast or as fully as one might expect given the high rate of spending. Most of the major space acquisition projects are seriously behind schedule and over budget, raising concerns that some U.S. capabilities will actually decline if new satellites cannot be launched before the old ones stop working. For example, the NRO started planning in the mid-1990s to replace its handful of electro-optical and radar satellites with a Future Imagery Architecture (FIA) using a larger number of lighter, more capable electro-optical and radar satellites to watch more of the Earth at one time, to revisit locations of interest more often, to see through clouds, and to integrate the satellite data with other intelligence information. Unclassified information is scarce, but the program appears to have been officially terminated in 2005 after billions of dollars had already been spent but Boeing had delivered no new satellites and projected cost estimates had ballooned from $5 billion to as high as $18 billion. Lockheed Martin was then asked to resume production of an updated version of the old optical satellite that Boeing had promised to replace with a much more advanced version, but in late 2006, an

135. CBO, *Long-Term Implications,* 2. This CBO report projected that the space segment of space radar would cost $19 billion through 2024 based on the rough calculation that the total weight of nine satellites would be about 7,000 pounds at a cost of $70,000 per pound. A subsequent CBO report used much more detailed calculations to conclude that the cost of a basic space radar system could range from $25 to $90 billion, potentially swamping all the rest of the programs in the military space acquisition budget.

experimental Lockheed Martin imagery satellite (NROL-21, also known as USA-193) failed to communicate with ground controllers after reaching orbit, and the delivery date for the first updated Lockheed model has slipped to 2009.[136] The intelligence community is trying to save fuel and extend the lifetime of its few on-orbit classified satellites by using commercial optical imagery, but at least one of the 1990s radar satellites has passed the end of its service lifetime, and no commercial substitute exists for radar imagery. Rather than having an unblinking eye in the sky, the NRO is more likely to be watching from space with one eye closed for the next few years.[137]

Nearly all of the military space acquisition programs have experienced at least one Nunn-McCurdy Amendment violation—that is, cost overruns have exceeded the baseline cost by at least 15 percent. The SBIRS program to provide information for missile warning, missile defense, and battlespace characterization is the most egregious public example. Since its inception in 1994, the SBIRS-High program has experienced four Nunn-McCurdy breaches; projected cost has soared from $2 billion to $10 billion; the number of planned satellites have been reduced; its detection and data-processing technologies are no longer state-of-the-art; the launch date for the first GEO satellite has slipped until late 2009 or 2010; software and hardware problems persist; and a spacecraft with similar design features failed in testing.[138] The first SBIRS sensor hosted by a classified satellite in highly elliptical orbit was declared operational in November 2006, but the United States must still primarily rely on Defense Support Program (DSP) satellites first launched in the 1970s to watch for missile launches. The last available DSP satellite was launched in November 2007, exacerbating concerns that U.S. missile warning capability could deteriorate if the SBIRS schedule continues to slip.[139]

The military has a mixed record on making fuller use of existing space-based assets to support ongoing operations. Defense analysts cite the rapid growth of satellite communications bandwidth used in recent wars as evi-

136. Philip Taubman, "In Death of Spy Satellite Program, Lofty Plans and Unrealistic Bids," *New York Times,* November 11, 2007, 1.

137. Jeffrey T. Richelson, "The Satellite Gap," *Bulletin of the Atomic Scientists* (January/February 2003): 48–54.

138. The SBIRS program has repeatedly been restructured, with the current plan being to purchase three dedicated SBIRS satellites instead of the original five. DOD initiated a parallel effort by a different set of defense contractors to develop an alternative infrared sensor technology to compete with and potentially replace SBIRS, but that project has run into comparable problems. While the U.S. Government Accountability Office (GAO) predicts further delays and cost increases on SBIRS, the Secretary of Defense has directed the Air Force to maintain the current schedule even if that requires a greater reduction in the capability of SBIRS. See GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs* (Washington, DC: GAO, 2007), 123–124, http://www.gao.gov/new.items/d07406sp.pdf; and GAO, "Space Based Infrared System High Program and its Alternative," Report No. 1088R, August 31, 2007, http://www.gao.gov/new.items/d071088r.pdf.

139. Jeremy Singer, "SBIRS Report to Include Update on Health of Defense Support Program," *Space News,* December 8, 2004, http://www.space.com/php/spacenews/spacenews/archive04/sbirsarch_121604.html; and Andy Pasztor, "U.S.'s Lofty Plans for Smart Satellites Fall Back to Earth," *Wall Street Journal,* February 11, 2006.

dence that the U.S. military is becoming steadily more space-enabled. The Defense Information Systems Agency provided forty times the bandwidth to 40 percent fewer troops in Operation Iraqi Freedom compared with Operation Desert Storm, with communications satellites being the most reliable way to pass large amounts of information to dispersed forces. Yet, network-centric concepts of warfare are so information-intensive that this huge increase in bandwidth was deemed woefully inadequate.[140] Moreover, commercial firms, including Iridium, provided 80 percent of the satellite communications bandwidth used during Operation Iraqi Freedom compared with 20–30 percent in the early 1990s, partly due to delays in upgrading the military's own space-based communications systems.[141]

A mostly classified RAND report on the initial phase of the Iraq war found a space-based digital divide. Commanders at headquarters in Qatar and Kuwait had a remarkably clear picture of the location and movements of friendly units (via the Blue Force Tracker system) and of many Iraqi targets. Sometimes they received more information than they could process and had to turn off their airborne sensors. Frontline army commanders, on the other hand, had "terrible situational awareness": mobile units outran communications relays; several units were attacked when they stopped to receive intelligence on enemy positions; and bandwidth and software problems often caused computers to freeze for hours at a time. Impressive achievements, such as the use of GPS-guided bombs to attack an Iraqi Republican Guard unit during a blinding sandstorm, coexisted with striking failures, as when a U.S. battalion commander approaching a key bridge on the road to Baghdad received no warning of an impending ambush by three sizeable Iraqi brigades closing in from different directions.[142]

Although force enhancement programs have been receiving most of the money and attention, several independent analysts have been trying to track current spending on research and development projects related to the space control and force application missions.[143] These analysts, in attempting to

140. Gopal Ratnam, "Bandwidth Battle," *Defense News,* October 9, 2006, 35–40.

141. Warren Fester, "War Bonanza for Satellites: Military Bandwidth Demand Energizes Slow Market," *Defense News,* September 1, 2003, 31.

142. Findings from the RAND report are described in David Talbot, "How Technology Failed in Iraq," *Technology Review,* November 2004, http://www.technologyreview.com/read_article.aspx?id=13893&ch=infotech.

143. For analyses of space weapons in the FY2004–FY2008 budget requests, see Jeffrey Lewis, "Lift-Off for Space Weapons: Implications of the Department of Defense's 2004 Budget Request for Space Weaponization," CISSM working paper, Center for International and Security Studies at Maryland, July 2003, http://www.cissm.umd.edu/papers/files/spaceweapons.pdf; Jeffrey Lewis and Jessy Cowan, "Space Weapon Related Programs in the FY 2005 Budget Request," Center for Defense Information (CDI), March 2004, http://www.cdi.org/news/space-security/SpaceWeaponsFY05.pdf; Theresa Hitchens, Michael Katz-Hyman, and Jeffrey Lewis, "U.S. Space Weapons: Big Intentions, Little Focus," *Nonproliferation Review* 13, no. 1 (March 2006): 35–56; Theresa Hitchens, Michael Katz-Hyman, and Victoria Samson, "Space Weapons Spending in the FY 2007 Defense Budget," CDI and Henry L Stimson Center, March 2006, http://www.cdi.org/pdfs/FY07

match SPACECOM's aspirations with specific funding requests in DOD's five-year defense program budget (FY2006–FY2009), found little evidence of a coherent spending plan to implement the space warfighting strategy. Instead, small amounts of money were being used to create a "technological sandbox" in which scientists could do basic research into a wide array of concepts that might someday lead to miniature propulsion units for microsatellites, directed-energy weapons, reusable space planes, and other futuristic systems.[144] Little or no money was being spent for ground- or air-launched anti-satellite capabilities that could be acquired relatively quickly. Instead, the emphasis was on ambitious projects that were a decade or more away from completion. Unclassified spending on anti-satellite weapons, space-based missile defense interceptors, and space-based strike weapons totaled less than $300 million in the FY2006 request, suggesting that Bush administration support for these programs was more rhetorical than real.[145]

Even in their embryonic form, however, certain projects could undercut the existing rules and restraints on military space activities without providing more reliable unilateral protection for U.S. space assets. In fall 2004, the United States deployed its first dedicated ground-based system to disrupt other countries' access to satellite communications. These jammers interfere with the radio-frequency links between satellites and receivers, not with the satellites themselves. Nevertheless, they raise important legal questions about disrupting others' freedom to use space in the same ways that the United States does (OST, article 1), especially if the interference affects not only a belligerent state but also neutral parties using signals from the same satellite. The Air Force defines these jammers as counterspace weapons and has depicted Iraq's use of similar GPS jammers as evidence that space warfare is already occurring. That interpretation undermines the traditional barrier between military support and direct weapons use.

Recent budget requests have also contained money for several "Autonomous Proximity Operations" involving microsatellites that can maneuver close to other satellites and perform missions such as in-orbit repairs and refueling a satellite to extend its service life. The Experimental Satellite System (XSS) program has launched several satellites to demonstrate close-proximity inspection operations. While these are not dedicated anti-satellite weapons, they could be used in that mode. The XSS is the successor to the Clementine 2 Asteroid Intercept Demonstrator that President Clinton line-item vetoed in 1997 and that an Air Force study recommended be revived

spaceweapons.pdf; and Theresa Hitchens, Victoria Samson, and Sam Black, "Space Weapons Spending in the FY 2008 Defense Budget," CDI, February 2007, http://www.cdi.org/PDFs/Space%20Weapons%20Spending%20in%20the%20FY%202008%20Defense%20Budget.pdf.

144. The phrase "technological sandbox" comes from an interview with Richard Garwin in the documentary film *Arming the Heavens: The Push for Space Weapons* (Washington, DC: Azimuth Media, 2004).

145. Hitchens, Katz-Hyman, and Lewis, "U.S. Space Weapons," 48.

for possible use as an ASAT weapon.[146] International suspicion is likely to grow if such dual-use technology continues to be developed without transparency measures and explicit rules for legitimate use.[147]

The budget documents also provide information about a largely secret Air Force project to develop a ground-based anti-satellite laser that would use advances in optical technology to compensate for atmospheric turbulence, enabling concentrated beams of light to destroy targets in space. The telescopes at the Starfire Optical Range have been using adaptive optics on incoming light to improve the telescopes' ability to image satellites and identify small objects in orbit. The FY2007 budget request, however, included the use of adaptive optics on outgoing light to "demonstrate fully compensated laser propagation to low earth orbit satellites" for purposes including anti-satellite operations.[148] Congress raised questions, so the FY2008 budget documents emphasize the project's utility for space surveillance and no longer mention ASAT uses. Although potential weapons applications are said to be "years and years and years into the future," funding these near-term experiments under any justification moves the United States further in that direction.[149]

Two missile defense projects could soon cross the normative threshold against space weapons. In August 2007, MDA used a Near Field Infrared Experiment (NFIRE) satellite to collect images of a boosting U.S. rocket. An earlier plan for this first NFIRE experiment included firing a small sensor-equipped projectile (similar to "kill vehicles" used in other missile defense tests) down from the observation satellite to get a close look at the test missile.[150] After MDA acknowledged that the projectile might hit the test missile, congressional pressure caused MDA to drop that part of the experiment, but other members of Congress want MDA to restore the kill vehicle in a second round of NFIRE experiments.[151]

146. The FY2008 budget request included $28.9 million for the XSS program under the "integrated space technology demonstrations" budget line. An advertisement for the "Escort" inspection microsatellite trumpeted its anti-satellite applications, declaring that the Escort would be able to "monitor space around a large satellite to detect attacks, stealthily inspect and monitor a large satellite to determine its capabilities, stealthily attack to permanently or temporarily disable a large satellite, [and] actively defend a large satellite against attacks by microsatellites." See Hitchens, Katz-Hyman, and Lewis, "U.S. Space Weapons," 39–40. The Escort advertisement can be seen at http://www.aeroastro.com/datasheets/Escort.pdf.

147. Spacecraft capable of automated rendezvous and docking, such as the Russian Progress resupply vehicle, constitute another dual-use capability that could raise ASAT concerns if the space security environment became more precarious.

148. Quoted in William J. Broad, "Administration Conducting Research into Laser Weapons," *New York Times*, May 3, 2006.

149. Senior Pentagon official quoted in Broad, "Administration Conducting Research into Laser Weapons."

150. Jeremy Singer, "Experimental Missile Defense Satellite Delayed 1 Year," *Space News,* July 7, 2004.

151. When the kill vehicle was removed from the observation satellite, its spot was filled with a German laser communications payload that could also provide information for mis-

MDA has also made it increasingly difficult to determine the status of efforts to develop space-based missile defense interceptors. For years, the MDA claimed that no decision had been made about a space-based layer in a future missile defense system and that no money was currently being spent on tests in space. Yet, the FY2006 budget request called the space test bed "an essential element of our BMDS acquisition plan" and requested $673 million through FY2011 to prepare for a series of space-based interceptor tests.[152] The FY2007 budget request included funding for several microsatellite experiments that were related to space-based missile defense and anti-satellite weapons. One experiment was described as using microsatellites to provide three-dimensional tracking information, one as using propulsion systems to guide maneuverable satellites, and one as developing cooperative targets for missile defense (or anti-satellite) tests. All three experiments would be logical candidates for a space test bed.[153] In the unclassified part of the FY2008 budget request, MDA included only $10 million to begin work on the space test bed itself (down from the $45 million that MDA had said it would request for the space test bed in FY2008) and projected a total request of only $290 million through FY2013.[154] Congress zeroed out the space test bed request in the FY2008 budget request, but because classified spending on missile defense has increased significantly in recent years and because MDA has not announced that it will scale back or slow down its plans to develop a space-based layer for missile defense, MDA might have responded to congressional opposition by moving work on the space test bed into the black budget.[155]

The FY2008 defense appropriations bill also includes $100 million for a revised version of the FALCON program as a potential "prompt global strike" alternative to using nuclear weapons or long-range ballistic missiles with new conventional warheads. This version of the space bomber concept involves a reusable hypersonic cruise vehicle (HCV) that could strike targets up to 9,000 nautical miles from the continental United States in less than two hours. The HCV would not be stationed in orbit but would be launched into space on a small rocket when an attack was ordered, then would fly above national airspace to its target (obviating the need for overflight permission), deliver its payload, and return to the United States. This project, too, is in the early stages of what DOD envisions as a two-decade development process. There-

sile defense. The 2006 Defense Appropriations Act included language that encouraged MDA to restore the kill vehicle, but it would take at least two years to complete the kill vehicle and integrate it into an NFIRE satellite. See Jeremy Singer, "STSS Satellites Could Benefit from NFIRE Demo," *Space News,* April 6, 2006.

152. Quoted in Sam Black, "Evolution of the Space Test Bed," CDI, March 2007, http://www.cdi.org/friendlyversion/printversion.cfm?documentID=3884.

153. Hitchens, Katz-Hyman, and Samson, "Space Weapons Spending in the FY 2007 Defense Budget."

154. Hitchens, Samson, and Black, "Space Weapons Spending in the FY 2008 Defense Budget."

155. Black, "Evolution of the Space Test Bed."

fore, the main use for the current money will be to help develop small rockets that could be launched on short notice for a variety of different purposes.[156]

In general, the Bush administration has been trying to spend as much money as Congress will allow on acquiring new military space capabilities, with annual requests that continue to rise despite congressional pressure for cost reductions and reallocations. So far, however, increased spending has not been matched by comparable advances in capabilities. Growing budget scrutiny and cost constraints have stimulated debate about whether the United States should devote even more of its military space acquisition budget to completing Clinton-era upgrades or whether it should leapfrog over next-generation satellites and invest more heavily in research on transformational systems that are at least a decade from deployment. The more fundamental question is whether a sustained commitment to either the incremental or the revolutionary acquisition route could reasonably be expected to reach the full SPACECOM vision. The experience of the past five years suggests that no matter how hard the Bush administration or subsequent U.S. leaders try, the costs and technical challenges of—not to mention other countries' probable military reactions to—unilateral space security will keep total dominance out of reach.

Program Management

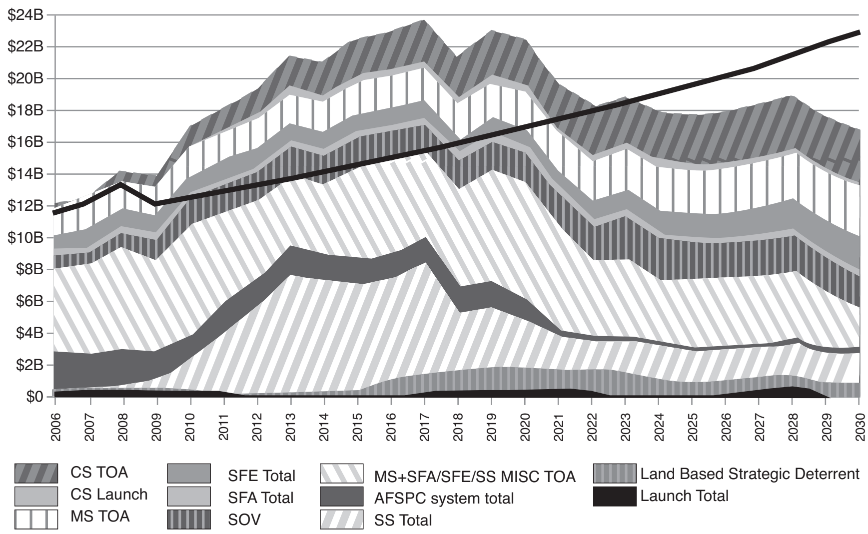
Even with optimistic assumptions about future funding levels and the cost of acquiring new space capabilities, the AFSPC has acknowledged that "to acquire all the capabilities for which AFSPC is responsible in the timeframes desired by the warfighter" would be impossible.[157] The *Strategic Master Plan* includes a chart (reproduced in Figure 4) that contrasted AFSPC's assumptions about its total obligation authority (TOA) through 2030 (the black line) with the estimated costs of acquiring new capabilities by mission area. The AFSPC analysis shows a modest gap between resources and anticipated costs in the Future Years Defense Plan, then a budget shortfall approaching 50 percent as desired systems move into the more expensive stages of research, development, and procurement. AFSPC tersely notes that the current plan is "unexecutable." While this type of language is commonly used as a tactic to increase resources in budget battles, if it accurately represents or understates the magnitude of the problem and more resources are not likely to be provided, then the plan is unlikely to achieve its stated purposes.

The *Strategic Master Plan* proposes to worry about the projected funding shortfall later; it recommends relaxing some TOA constraints (i.e., continuing to pursue more development projects than could be completed without future TOA growing faster than 3 percent per year) and postponing the start of significant work on Operationally Responsive Space Launch until 2020. Given the high costs of the war in Iraq and other ongoing military opera-

156. Walter Pincus, "Space Bomber Program Gets Extra Funding," *Washington Post,* November 12, 2007.

157. AFSPC, *Strategic Master Plan,* 13.

Figure 4: Mismatch between SPACECOM plans and resources



Source: AFSPC, *Strategic Master Plan FY06 and Beyond,* p. 13. The black line shows that AFSPC had about $12 billion in Total Obligation Authority (TOA) for FY2006. Projected TOA through FY2009 reflects the Future Years Defense Plan submitted with the Bush administration's FY2006 request and thereafter assumes three percent real growth in TOA. SFE = Space Force Enhancement, CS = Counterspace, SFA = Space Force Application, SS = Space Support, and MS = Mission Support.

tions, as well as mounting concerns about the U.S. federal budget deficit, to assume that the rate of spending on military space acquisition will grow even faster than currently projected is unrealistic.

Proponents of the SPACECOM VISION believe that the United States should spend whatever it takes to acquire unique capabilities that could confer significant military advantages. Yet, recent experience shows that the AFSPC analysis significantly underestimates the long-term cost of acquiring its desired capabilities. The head of Boeing's defense unit has publicly complained that schedule and cost projections used in SPACECOM plans were "unrealistic" and "assumed everything was going to work the first time."[158] The space acquisition process has not become "faster, better, cheaper," as NASA administrator Daniel Goldin promised more generally in the late 1990s. Instead, by reducing the number of civil servants with space acquisition expertise and relying more on contractors, the U.S. government lost much of its professional capability to assess space acquisition proposals just as the SPACECOM program moved into high gear. The result is a situation where the cost growth associated with current major space acquisition projects has generally been between 50 and 100 percent from the time of contract initiation.[159] That suggests that even if U.S. spending on

158. Andy Pasztor, "U.S.'s Lofty Plans for Smart Satellites Fall Back to Earth," *Wall Street Journal,* February 11, 2006.

159. GAO, *Space Acquisition: DOD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems,* report prepared for the Subcommittee on Strategic Forces of the House Committee on Armed Services, GAO-07-96, November 2006, 1. U.S. policy requires that independent cost and schedule estimates be prepared but not that they be relied upon

military space capabilities remains vastly greater than everyone else's, achievement of its stated aspirations is doubtful because it will not be able to acquire all the necessary capabilities.

Like the SBIRS program, a number of major space acquisition programs fit a pattern in which DOD's rush to develop complex new weapons systems based on immature technology and inadequate knowledge has led to major cost overruns, quantity reductions, per unit cost increases, and performance shortfalls.[160] Contrary to predictions that advanced information technology and the integration of satellites into a "system of systems" architecture would provide much greater capabilities at much lower costs, these technological trends and the post–September 11, 2001, surge in U.S. defense spending are increasing the costs and uncertainties associated with transformational military projects.[161] The United States is the undisputed front-runner when it comes to military space spending, but the faster it runs, the more it seems to trip over its own feet.

The evident deficiencies of the military space acquisition process have deep roots. A 2003 Defense Science Board/Air Force Scientific Advisory Board report (the "Young Panel") identified serious systemic problems, including undisciplined definition of and uncontrolled growth in requirements, an acquisition process biased to produce unrealistically low cost estimates, an erosion of engineering and managerial competence among government overseers, and industry failure to follow best practices.[162] The GAO observed that "DOD starts more programs than it can afford over the long run, forcing programs to underestimate costs and overpromise capabilities" in order to get funded each year. Senior defense officials do not want to make difficult choices among space programs or scale back the desired capabilities in response to budget shortfalls, so product developers "pursue exotic solutions and technologies that can, in theory, do it all"—a form of denial that perpetuates the problem.[163]

in making major space acquisition decisions. The number of Air Force cost estimators available to work on these independent assessments has decreased from 680 to 280, and the amount of information they have to work with has also decreased. Also, the current rate of cost growth in space acquisition programs is even higher than the historical average used by the CBO assessment in Figure 3.

160. GAO, *Defense Acquisitions,* 9–11; and GAO, *Space System Acquisition,* assessment prepared for the Chairman of the Subcommittee on Defense of the House Committee on Appropriations, June 23, 2005, http://www.gao.gov/new.items/d05570r.pdf.

161. On the defense sector's failure to realize economic gains from information technology comparable to those in other IT-rich sectors, see David C. Gompert and Paul Bracken, "Bringing Defense into the Information Economy," CTNSP Defense and Technology Paper no. 28, Center for Technology and National Security Policy, National Defense University, Washington, DC, March 2006, http://www.ndu.edu/ctnsp/Def_Tech/DTP%2028%20Bringing%20Defense%20Into%20the%20Info%20Economy.pdf.

162. *Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs,* Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, May 2003, 2–4, http://www.acq.osd.mil/dsb/reports/space.pdf.

163. GAO, *Space System Acquisition,* 7–9.

Concerted efforts to reform the space acquisition process have not improved the results. Two years after the Young Panel report, congressional appropriators judged that space acquisition programs "have collectively gotten worse" and could deteriorate even further:

> the same space-acquisition professionals (both in the government and in industry) that are struggling to execute the current level of investment will soon face greater challenges managing the additional programmatic content and complexity that comes with the budget ramp-up. Unless DoD takes significant corrective action, the Committee is very concerned that the space acquisition workforce may not meet these challenges effectively. In fact, the Committee is concerned whether DoD is in a position to make appropriate choices regarding which programs to pursue given the systemic deficiencies that reduce the availability of good data (cost, technical maturity, acquisition approach, schedule) to senior leadership.[164]

Supporters of the SPACECOM program understand that massive cost overruns and development delays are eroding congressional support for major projects that are integral to plans for U.S. military space dominance, defense transformation, and the coercive prevention strategy. Senator Wayne Allard told the National Defense Industrial Association that "the Air Force and its contractors have lost all credibility with Congress when it comes to space acquisition" and that "continued mismanagement of our space acquisition programs is a far greater threat to our space dominance than any external threat."[165] But much as Allard and senior SPACECOM officials might like to believe that military space acquisition problems can be rectified by slowing the pace, relying more on proven technology, and reorganizing management, informed observers have come to believe that the factors driving the exorbitant costs of high-tech military acquisition in general, and space projects in particular, "have become so widespread and chronic that they threaten to undermine the viability of the entire transformation agenda."[166] Simon "Pete" Worden, a retired senior Air Force officer with a long history of support for expanded U.S. military space activities, has observed that "the most compelling case against space weapons is that the U.S. space industry and associated military space leadership are incapable of delivering any space capability, let alone a space weapon."[167]

164. House Committee on Appropriations, *Report on Department of Defense Appropriations Bill, 2006,* 109th Cong., 1st sess., 2005, H. Rep. 119, section on "Problems in DOD Space Programs."

165. Wayne Allard, speech to the "Space Policy and Architecture Symposium," of the National Defense Industrial Association, Arlington, VA, September 23, 2005, http://www.globalsecurity.org/space/library/news/2005/space-050923-ndia-allard.htm.

166. Loren B. Thompson, *Can the Space Sector Meet Military Goals for Space? The Tension between Transformation and Federal Management Practices* (Arlington, VA: The Lexington Institute, 2005), 5. The report is available at http://www.lexingtoninstitute.org/docs/662.pdf.

167. Simon Worden, "High Anxiety," *Bulletin of the Atomic Scientists,* March/April 2006, 22.

The fixation on unilateral military space dominance contributes to military space acquisition problems in several ways. First, trying to revolutionize U.S. military space capabilities on an accelerated schedule in an atmosphere of radical uncertainty about future threats, missions, and technologies is bound to produce expensive programs that cannot provide all the promised results. Getting diverse parts of the U.S. military, intelligence, and homeland security communities to agree on required capabilities that should be designed into satellites that will not be deployed for a decade or more is difficult enough. Even more challenging is coordinating space acquisition projects with North Atlantic Treaty Organization (NATO) allies who recognize the benefits of interoperable communications and navigation systems but who lack SPACECOM's lavish acquisition budget and do not share its highly adversarial view of space security.[168]

Second, tighter export controls have increased the U.S. commercial space industry's dependence on the Defense Department and raised the costs and risks associated with developing new military space capabilities. Contractors who are desperate to make the winning bid for a small number of lucrative, long-lead-time development projects are likely to promise whatever the sole customer wants, on the fastest possible schedule and at the lowest possible price, in the expectation that requirements, schedule, and cost will be adjusted after the project is underway. Moreover, as the primary customer, the DOD must provide more investment funding, pay a larger portion of fixed costs, and shoulder more responsibility for keeping contractors in business than it would if the commercial side of the U.S. space industry was flourishing. For example, the government's share of the EELV program, a government-industry partnership intended to reduce the life-cycle cost of launching large satellites, had nearly doubled by 2005 over the $18.8 billion baseline approved in 2002, with a little more than half of the increase due to the lack of a commercial market.[169]

Some international cooperation that could reduce costs is precluded altogether, and other forms of cooperation are constrained with damaging results. In April 2005, the $110 million Demonstration of Autonomous Rendezvous Technology (DART) close proximity experiment failed when the DART spacecraft used up most of its fuel too quickly, then collided with a military communications satellite and knocked it out of orbit. NASA cited export control concerns as the reason why the official DART Mishap Investigation Board report was not publicly released, but a summary of the board's report indicates that "insufficient technical communication between the project and

168. Xavier Pasco, "A European Approach to Space Security," CISSM working paper, Center for International and Security Studies at Maryland, July 2006, 5–6, http://www.cissm.umd.edu/papers/files/pasco2006.pdf.

169. GAO, *Defense Space Activities: Continuation of Evolved Expendable Launch Vehicle Program's Progress to Date Subject to Some Uncertainties,* report prepared for the House Subcommittee on Strategic Forces of the Committee on the Armed Services, June 24, 2004, GAO-04-778R, http://www.gao.gov/new.items/d04778r.pdf; and Michael Fabey, "Many Factors Boost Military-Launch Costs," *Defense News,* May 16, 2005, 20.

an international vendor due to perceived restrictions in export control regulations did not allow for adequate insight."[170] The summary does not specify how restrictions on the exchange of technical information contributed to the errors that caused DART to collide rather than rendezvous with its cooperative target. Even without sensitive details, though, the summary is a useful reminder of how easily things can go wrong and how greatly small mistakes can matter when operating in outer space.

Finally, many senior political leaders who have embraced the SPACECOM vision lack the technical training to understand the scientific and engineering challenges involved. As one observer generally sympathetic to SPACECOM remarked:

> During the Cold War, the performance requirements of key military systems were driven mainly by what was known about the dominant threat. In a "capabilities-based" planning environment, there is much more latitude for imagination. But if senior decisionmakers lack a grasp of technological realities, then the possibility of unexecutable requirements would exist even in an otherwise optimal acquisition system.[171]

From what can be discerned from available information, the magnitude of expenditure, the specific allocation to development projects, and the overall management of the weapons acquisition process do not appear sufficient to overturn the traditional presumption that decisive dominance in space cannot be achieved.

PLAUSIBLE PROSPECTS

Could dominance in space be achieved if adequate resources were provided and effectively managed? American space enthusiasts are fond of citing the Apollo program as evidence that the United States can mobilize the economic resources to overcome major technical challenges on a tight timeline when its leaders have a bold and inspirational vision. Some basic physical laws and technical facts impose unavoidable constraints on space operations, however. They give reason to question whether U.S. military space dominance could be achieved with any plausible multiple of the current effort, regardless of how well it might be managed.

The requirements of launching, maneuvering, and operating satellites in space impose greater burdens and more constraints than are encountered in other environments. In order to stay aloft, satellites to be inserted into LEO (100–2,500 km) need a velocity of 7–8 km/sec—thirty times faster than a passenger plane—when they reach their target altitude. Those to be placed in geosynchronous orbit (36,000 km) often are first launched into a LEO park-

170. "NASA Report: Overview of the DART Mishap Investigation Results–For Public Release," May 15, 2006, http://www.spaceref.com/news/viewsr.html?pid=20605.

171. Thompson, *Can the Space Sector Meet Military Goals for Space?* 29.

ing orbit, then maneuvered into their operational position, where they travel at about 3 km/sec. The energy necessary to impart these velocities is substantial—to launch a satellite into LEO, approximately 45 tons of propellant are needed for every ton of payload. Fuel requirements for each subsequent maneuver increase exponentially with the amount of velocity change (ΔV) needed to modify the satellite's orbital altitude. Low ΔV maneuvers such as changing orbital altitude might use a mass of propellant equal to 10 percent of the satellite's mass, whereas high ΔV maneuvers such as changing a satellite's orbital plane could require a mass of propellant many times greater than the mass of the satellite itself.[172] These fuel requirements create practical limits on satellite weight and maneuverability.

Although ballistic missiles and launch rockets are similar, the extra velocity required to put a satellite in orbit makes that job harder in some respects than hitting a target on Earth or in space. As a general rule, a ballistic missile that can deliver a payload at maximum range R could loft that payload to an altitude R/2 and would need significantly more thrust to get that payload up to orbital speed. Modern rockets typically can put into LEO only satellites whose weight is a small fraction of the rocket's total mass at liftoff and can put less than half that much satellite mass into GEO. Some short-range missiles, such as the Scud B (range, 300-km), could disperse a cloud of small pellets at lower LEO altitudes where they could cause significant damage to speeding satellites, but the Scud would not have enough velocity for its payload to remain in orbit. If a developing country wanted to convert an intermediate-range missile into a KE ASAT, it would face severe technical challenges in building a kill vehicle that could home in on the satellite and guide itself precisely enough at high speed to intercept the satellite.[173] Countries that want to parlay their missile programs into indigenous space-launch programs—such as North Korea's unsuccessful attempt to launch a LEO communications satellite in 1998 and India's efforts to develop cryogenic rockets that could put heavy satellites into GEO—will necessarily also extend their missile capabilities even if that is not their primary objective.[174]

Space activities are intrinsically expensive because of the specialized components required to operate in space, the high costs of launch, and the many uncertainties involved. Available estimates of the initial cost of a satellite can

172. New propulsion technologies under development could reduce the amount of fuel needed to accomplish different maneuvers, but none of the propulsion technologies likely to be available in the foreseeable future could be used for rapid movements. See Wright, Grego, and Gronlund, *The Physics of Space Security,* 71–74.

173. Jaganath Sankaran, "Requirements and Feasibility for the Transition from a Ballistic Missile Capability to an Anti-Satellite (ASAT) Capability," CISSM working paper, Center for International and Security Studies at Maryland, December 2007, http://www.cissm.umd.edu/papers/files/sankaran_ASAT.pdf.

174. In the Indian case, the proliferation concern was not that India would put cryogenic engines into ballistic missiles (the fuel is too unstable to use in missiles that must be stored for extended periods of time and possibly launched on short notice). Rather, the concern was that Indian engineers would learn things about other aspects of advanced rocket design that they could then adapt for use in their ballistic missile program.

range from $15 to 20 million or more for a small satellite, to $100 million for a typical commercial satellite, to billions of dollars for a sophisticated spy satellite.[175] The figure most commonly used to represent the magnitude of launch costs to LEO is $10,000 per pound or $20,000 per kilogram of payload (the satellite plus the fuel needed for maneuvers), with satellite weight ranging from around ten kilograms for nanosatellites up to 4,000 kilograms for the MILSTAR communications satellite. The generic per-kilogram launch figure is highly misleading, though, because launchers rarely fly fully loaded, and the specifics of orbital altitude and inclination also affect launch costs. Actual per-kilogram costs for commercial non-GSO launches throughout the 1990s ranged from roughly $10,000 to $55,000 and higher, while per-kilogram GSO launch costs were around $25,000 by the end of the decade.[176] Little public information has been provided on actual commercial launch costs since 2000, and no comparable data are available for military launch costs, which could be significantly higher due to lack of competition or lower due to hidden government subsidies. Any use of space involving heavy satellites, large constellations, or significant maneuvering would include launch costs at least in the high tens to hundreds of millions of dollars.[177] Finally, insurance for launch and in-orbit operations currently adds about another hundred million to the cost of an average commercial satellite—a figure that could easily rise much higher if debris, space traffic management problems, or space warfare increased the risks associated with space operations.[178]

Exorbitant costs have long been considered a major impediment to the realization of transformative space ambitions, whether they involve the wide-

175. Frank Morring Jr., "Smallsats Grow Up," *Aviation Week & Space Technology,* December 8, 2003, 46. The estimated cost of small satellites comes from Sir Martin Sweeting, director of the Surrey Space Centre. Some people claim that small satellites can be built for only a few million dollars, but this capability is not widely demonstrated yet, and the small satellites built for DOD's TacSat program have cost about $40 million apiece. U.S. spy satellites are commonly said to cost about a billion dollars, but the director of national intelligence used the higher figure in Mike McConnell, "Overhauling Intelligence," *Foreign Affairs,* July/August 2007, 58. The actual costs to produce a satellite or launch vehicle can be quite different from what a commercial company might charge for that launch.

176. During the 1990s, commercial launches to GSO on average used 80–90 percent of the vehicle's carrying capacity, while launches to lower altitudes used less than half of the carrying capacity even when they had more than one satellite on board. Futron Corporation, *Space Transportation Costs: Trends in Price per Pound to Orbit, 1990–2000* (Bethesda, MD: Futron Corporation, 2002), http://www.futron.com/pdf/resource_center/white_papers/FutronLaunchCostWP.pdf.

177. *The Space Report 2006* (30–31) has cost data for 18 out of 55 launch events in 2005. Twelve of the 18 involved the launch of a single communications satellite into GEO for $70 million per launch. The three other GEO launches also involved communications satellites and had launch costs ranging from $40 million to $140 million. Costs for the three LEO launches were much lower ($1.15 to $13 million), but these were much lighter satellites and two out of three launches were failures.

178. Andrea Maléter, "Strategies to Mitigate High Satellite Insurance Premiums," *Satellite Finance* 64, December 10, 2003, 46–47, http://www.futron.com/pdf/resource_center/reports/SatFinanceAMaleter.pdf.

spread commercialization of space envisioned at the end of the Cold War, the total U.S. military dominance of space currently sought by SPACECOM, or the colonization of space that inspires some futurists. Yet, decades of effort to dramatically reduce launch costs have produced remarkably little change.[179] The two highest profile U.S. government efforts to develop lower-cost launch options, the Space Shuttle and the EELV programs, used wildly optimistic assumptions to project huge cost savings that were not achieved.[180]

Many theories have been proposed for why launch costs have remained so high and whether they could be reduced enough to initiate a virtuous cycle of increasing use of space at decreasing cost. The most likely reasons, though, involve basic characteristics of space activity that would be difficult to change. Aerospace analyst Peter Taylor reviewed 19 explanations and concluded that the "principle proximate cause" is the "lack of intact abort capability;" that is, space flight is much more expensive than air flight because most problems cannot be fixed after takeoff. Because space vehicles are complex systems designed on the technical edge to maximize performance-to-weight ratios, multiple redundant subsystems and a huge "standing army" of experts are used to make sure that nothing goes wrong. Yet, these safeguards add new design challenges, increase complexity, and create new potential reliability problems.[181]

John London offered a similar technical explanation compounded by a public goods problem created by the size of initial investment needed for substantial technological innovation in space. Making extensive use of advanced technology to reduce significantly the recurring costs of spaceflight would require huge development costs that are hard to justify without unre-

179. One study that used "man-years of labor per million grams to LEO" as a metric to analyze historical trends found that launch costs have remained essentially flat since the first decade of orbital space operations. See Dietrich Koelle, *TRANSCOST: Statistical-Analytical Model for Cost Estimation and Economic Optimization of Space Transportation Systems* (1991), quoted in London, "Reducing Launch Cost," 116.

180. Space Shuttle proponents initially claimed that they could reduce launch costs to LEO by a factor of ten or more by using completely reusable launch vehicles that would need little maintenance and could make weekly flights. As it turned out, the Air Force added design requirements that increased the Shuttle's base cost, it is only partially reusable, it needs expensive maintenance, and it flies at most eight missions per year; it is also not available for commercial use, and each flight costs NASA several hundred million dollars. EELV proponents set a more modest goal of reducing the government's recurring launch costs by 25 percent, but this assumed that customers in a rapidly expanding commercial launch market would pay for most of the fixed costs of the EELV. Demand for commercial launch services has been much lower than expected and foreign launch providers offer comparable capabilities at much lower prices. The government's share of the total EELV program cost is now estimated to be $32 billion, nearly double the original estimate of $17 billion. See London, "Reducing Launch Cost," 136; and GAO, *Defense Space Activities*.

181. Peter Taylor, "Why Are Launch Costs So High?" (September 2004), http://home.earthlink.net/~peter.a.taylor/launch.htm. See also John Jurist et al., "When Physics, Economics, and Reality Collide: The Challenges of Cheap Orbital Access" (paper presented at the "Space 2005" conference, American Institute of Aeronautics & Astronautics, Long Beach, CA).

alistic assumptions about future rates of use and recurring costs. When governments consider funding extremely expensive development projects, strong pressures are exerted to use existing technologies and personnel, so recurring costs end up being as high as they were before.[182] Private industry might be more innovative and cost conscious, but it is less able and willing to invest heavily in high-risk development efforts without a guaranteed market for launch services, and it is more likely to operate in ways that increase reliability concerns.[183]

SPACECOM supporters understand that high launch costs—and related issues such as length of time to launch a satellite—pose serious challenges for their vision of space dominance. They propose to develop "operationally responsive spacelift" (ORS) to provide "orders of magnitude reduction in cost, significant improvements in responsiveness and greater reliability" so that they could quickly replace damaged satellites, meet short-term specialized ISR needs, and afford to deploy much larger constellations of satellites than are currently practical.[184] They hope to accomplish this, however, with low initial government investments. In the acquisition plan that AFSPC deemed "unexecutable" (see Figure 4), the "space operations vehicle" budget category balloons after 2009. Therefore, AFSPC wants to defer any significant spending on new launch vehicle development until 2020 or later, and is instead awarding small contracts for preliminary ORS work and hoping that entrepreneurs will absorb most of the up-front development costs, a strategy that appears likely to be derailed by the problem London identified.

Many companies submitted ORS concept proposals to DARPA in 2003, but the two that remain in the design competition are a long way from meeting the ORS goals, so the one ORS launch that has occurred used one of Orbital Science's Minotaur rockets.[185] AirLaunch LLC has completed successful test

182. London, "Reducing Launch Cost," 130–131.

183. After Orbital Science's Pegasus air-launch system suffered a few early failures in the 1990s, increased oversight and improved quality control drove the cost of a small-sat launch up from $6 million to $20–25 million, making it now one of the most expensive launch options. Some strategies to lower launch costs, such as design simplification, greater standardization, and more robust design margins, could also improve reliability. But it will be hard for capital-constrained companies that must start small in terms of the size of the satellites they launch or the number of launches they do per year to develop the track record needed to persuade customers that they should put at risk large, expensive satellites in order to save some small fraction of the satellite's value in launch costs.

184. AFSPC, *Strategic Master Plan,* 13. The Air Force also uses the term *responsive space* for the more limited objective of building and launching small satellites for short-term tactical objectives, such as persistent reconnaissance in a location that is not well covered by existing ISR satellites.

185. Jeff Foust, "Operationally Responsive Spacelift: A Solution Seeking a Problem?" *The Space Review,* October 13, 2003, http://www.thespacereview.com/article/52/1; and Dwayne Day, "How to Tell Your ORS from a Hole in the Ground," *The Space Review,* December 31, 2007, http://www.thespacereview.com/article/1027/1. The acronym *ORS* is now used more broadly to refer to "Operationally Responsive Space," which includes the TacSat demonstration program to build and launch smaller, more affordable satellites. DOD provided its Plan for Operationally Responsive Space to congressional defense committees in April 2007.

drops from Air Force C-17 cargo planes but has yet to demonstrate that it could put satellites into orbit without expensive modifications to the planes, a problem that led to the cancellation of a prior DARPA air-launch project called RASCAL. This approach could, in theory, be an attractive way to launch lightweight ISR satellites, but it could not be used for heavier communications or early-warning satellites. Moreover, achieving the responsiveness goal (launch on a few days' notice) could require dedicated aircraft on standby, which would significantly raise overall per-launch costs unless the number of ORS air-launches is unexpectedly large.[186]

The other remaining ORS contender, the SpaceX Corporation, claims that it will be able to launch small satellites for around $7 million and larger satellites for $27 to $78 million. These price projections are questionable, though, because the first test of SpaceX's small Falcon 1 rocket failed in March 2006 and, after several postponements, the second test flight failed to reach its intended orbit.[187] Elon Musk, the owner of SpaceX, has invested $100 million of his own money and hopes to recoup his investment by developing another rocket (Falcon 9) that can compete with Boeing and Lockheed Martin for the more lucrative heavy-launch government contracts. Given the high cost and value of its satellites, the U.S. government wants to see a track record of 98 percent reliability for any commercial rocket that would compete with the EELV. Few customers who are not mandated to buy American launch services are likely to risk an expensive satellite on an unproven rocket when Russia already offers reliable GEO launches in the $70 million range.[188] Despite Musk's deep pockets and record of success in other high-tech ventures, making long-term space policy decisions based on the assumption that he, or anyone else, will finally succeed in reducing launch costs by a factor of ten any time soon is probably not prudent.[189]

186. A congressionally mandated review of future national security space-launch requirements noted SPACECOM's interest in ORS but found "little hard documentation that equated to a verifiable need." The review concluded that "embarking on an extraordinary effort to develop a launch system more responsive than those that already exist would not be cost-effective until needs are clearly stated, operational concepts are defined, and, most importantly, a family of candidate payloads is within view." See National Security Space Launch Requirements Panel (NSSLRP), *National Security Space Launch Report* (Santa Monica, CA: RAND Corporation, 2006), xix, http://www.rand.org/pubs/monographs/2006/RAND_MG503.pdf.

187. Brian Berger, "Falcon 1 Failure Traced to a Busted Nut," *Space.com,* July 19, 2006, http://www.space.com/missionlaunches/060719_falcn1_update.html; and "SpaceX Declares Falcon 1 Rocket Operational Despite Less than Perfect Test," *Space.com,* March 28, 2007, http://www.space.com/news/070328_spacex_falc1test_updt.html.

188. NSSLRP, *National Security Space Launch Report,* 35.

189. Musk is currently absorbing the extra development costs of design and procedure changes intended to increase reliability, but this venture has already proved far more expensive than he anticipated. Even before the March 2006 inaugural Falcon 1 launch failure, Musk had invested twice as much of his own money in SpaceX as he had anticipated. He described the rocket launch business as "a shortcut to making a large fortune into a small one" but declared his intention to keep trying to reduce the cost of launch by a factor of ten in hopes of revolutionizing how space is used. See Michael Fabey, "A Space Revolutionary,"

The physics of space also have important implications for the technical requirements and costs associated with different types of space operations. We have already seen why it is much easier and less expensive to use space for purposes that involve collecting and transmitting information over long distances compared with purposes that involve transporting large amounts of mass from the Earth into space (e.g., space-based global strike weapons) or significant maneuvering in space (e.g., military space planes or inspector satellites). The physics of space also affect choice of orbital altitude for different types of applications, numbers of satellites needed for episodic or continual coverage, and the relative difficulty of conducting and disrupting space activities. Some of these considerations apply to all types of space operations, while others vary depending on the orbital altitude that is best suited for a particular type of operation.

All satellite systems have a number of components that must smoothly function together for effective operation. These include the satellite itself, the ground station used to control it, and the up- and downlinks used for communication between the satellite and its control station as well as other receivers on the ground. The handful of incidents most commonly cited as real-world examples of space warfare include cases where ground-based jammers were used to overpower the GPS signals being sent down to ground-based receivers and cases where ground-based jammers were used to prevent satellite transponders from receiving signals being sent up for broadcast back down. A hostile state or terrorist group would need relatively little technical sophistication to attack a ground station or conduct some types of electronic interference. Standard military measures can be used against these kinds of low-tech terrestrial threats, albeit at additional expense.

Satellites, however, are intrinsically more vulnerable than terrestrial systems for performing similar functions. Because satellites move at high speeds, accidental or deliberate collisions with even tiny objects can have very damaging results. Satellites naturally move along a predictable path, and most can be tracked by amateur astronomers, so secrecy is not a reliable source of protection. Other means of passive protection commonly applied to planes, tanks, submarines, and ships, such as evasive maneuver or hardening, not only increase satellite and launch costs but also involve performance penalties and major practical constraints. Developing so-called bodyguard satellites is not be a reliable solution because of the difficulty of doing enough real-world testing to have confidence they would work and because they would be unlikely to provide persistent protection from a determined adversary. Finally, repairing a satellite in orbit is practically impossible, and replacing the more

Defense News, June 13, 2005, 54. A review of efforts to reduce launch costs reached the overall conclusion that even if some cost reductions were possible with a future increased rate of flight, "it still remains difficult today to project any costs less than $2,200/kg ($1,000/lb)." See Henry R. Herzfeld, Ray A. Williamson, and Nicolas Peter, *Launch Vehicles: An Economic Perspective* (Washington, DC: George Washington University Space Policy Institute, 2005), http://www.gwu.edu/~spi/publications/NASA%20L.Vehicle%20Study%20V-5.pdf.

valuable types of satellites could easily take years and cost hundreds of millions of dollars.

The number and placement of satellites in a constellation depends on their function, the territory to be covered, and the desired frequency of coverage. Continuous coverage of the entire Earth except the polar regions can be achieved with just three GEO satellites. This orbit is uniquely valuable for broadcast services and for communications systems that support users from widely different, nonpredetermined locations. Orbital physics limit the number of satellites that can be stationed in GEO, however, creating controversies over the allocation of scarce orbital slots and radio frequency spectrum both among different space-faring countries and between military and nonmilitary users.[190]

To defray the high costs of launching a satellite into GEO, commercial operators need to carry enough transponders to serve many different customers. If one of these communications satellites malfunctions, the consequences can be far-reaching. For example, a 1998 anomaly with a processor on PanAmSat Corporation's Galaxy IV satellite disabled most pagers in the United States for several days and prevented a major oil company's customers from paying for services at the pump.[191] Multitransponder satellites also pose a practical problem for counterspace operations because efforts to deny commercial satellite communications services to adversaries could also affect friendly and neutral users, which would violate international law even during wartime.

Some space applications, such as mobile telephone service, space-based missile defense, or high-resolution imagery, are best done by satellites in LEO.[192] The rapid speed with which LEO satellites move relative to the Earth means that the lower the orbit, the more satellites are needed to ensure that at least one is in position at any given time. The Iridium mobile phone system got its name because the constellation design required 77 satellites in 665 km polar orbits to provide anytime, anywhere coverage without excessive transmission delays or power requirements.[193] An American Physical Society (APS) study group calculated that at least 1,600 space-based interceptors stationed much closer to Earth (300 km) would be required to stop a single liq-

190. Theresa Hitchens, *Future Security in Space: Charting a Cooperative Course* (Washington, DC: CDI, 2004), 39–52.

191. GAO, *Critical Infrastructure Protection: Commercial Satellite Security Should Be More Fully Addressed,* report prepared for the Senate Permanent Subcommittee on Investigations of the Committee on Governmental Affairs, GAO-02-781, August 2002, 14, http://www.gao.gov/new.items/d02781.pdf.

192. Several companies use GEO satellites to provide mobile phone service, but they lack coverage at the northern- and southernmost latitudes, require bulkier equipment, and produce more appreciable echoes and delays.

193. Iridium is the 77th element of the periodic table. Eventually, the design was changed to require only 66 satellites in 780 km polar orbits, but the Iridium name was retained, perhaps because the 66th element, dysprosium, has a root meaning of "bad approach." Joe Flower, "Iridium," *Wired* 1.05 (November 1993).

uid-fueled intercontinental ballistic missile launched from Iran.[194] Although LEO satellites for some applications can be smaller, lighter, and less expensive than GEO satellites, the number needed to avoid absentee problems makes the total cost of a constellation quite substantial. Each Iridium satellite weighed about half a metric ton and was worth $45 million.[195] The APS study group calculated that a 1,600-interceptor system would require a total mass in orbit of at least 2,000 metric tones, necessitating at least a five- to ten-fold increase in total current U.S. annual launch capacity just to deploy this particular space system.[196]

Satellites in LEO are close enough to Earth that they would be vulnerable to a variety of ASAT attacks if legal and normative protections disappeared. Lasers can be used to temporarily dazzle or permanently blind optical sensors on remote imaging satellites. Moreover, any satellite in LEO could be damaged or destroyed using a missile that was much less capable than the rocket used to launch that satellite. A country with short-range missile capabilities could use an indiscriminate ASAT method to drive up the general cost and difficulty of operations in LEO, for example, by releasing a cloud of debris or detonating a nuclear explosion, but attackers would need sophisticated tracking and guidance skills to destroy specific satellites.[197] U.S. military satellites are somewhat better able to avoid or withstand these types of attacks than commercial or civilian satellites are, so if deliberate interference with satellites becomes more common, the softer targets are more likely to suffer.

The combination of satellite vulnerability and the high absentee ratio in LEO poses particular problems for space-based missile defense, because an adversary could create a hole in the constellation by destroying a few interceptors (or inducing them to fire in self-defense or at a decoy missile), then launching through the hole the next time it passed over a launch site. Satellite absenteeism also exacerbates the cost-effectiveness problem with missile defense, because designing a space-based interceptor system that could stop two missiles launched simultaneously from the same location would require twice as many satellites as a system designed to intercept only a single launch

194. APS Study Group, *Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues* (College Park, MD: APS, 2003), xxxvii–xxxviii.

195. When Iridium lost two satellites due to launch failures, the cost to Motorola (Iridium's parent company) was approximately $90 million. When Iridium stopped commercial service in August 2000, it had to figure out what to do with 88 satellites in orbit (66 operational, eight backup, and 14 defunct) whose total weight topped 53 U.S. tons. See MacCormack and Herman, "The Rise and Fall of Iridium," 10, 13.

196. APS Study Group, *Boost-Phase Intercept Systems,* xxxviii.

197. Some countries with short- or medium-range missiles also have the ability to develop homing interceptors, whereas others would have to use less sophisticated and potentially less effective types of ASAT attacks. Detonating a nuclear weapon in LEO would create an intense electromagnetic pulse that would destroy all unshielded satellites in the explosion's line of sight, as well as a persistent radiation environment that would slowly damage other unshielded satellites in LEO. Such an indiscriminate attack would be an act of desperation for any country, but might satisfy a terrorist's desire for shock and mass disruption.

at a time. Satellite vulnerability and absenteeism would also affect an offensive application of the interceptor system—that is, preventing other countries from launching objectionable satellites. But they would pose less acute problems because a missed intercept would result in a satellite in orbit that might be disabled or destroyed by other means before it could fulfill its threatening mission. Still, the physics of space make total space control essentially impossible; the physics also favor offense over defense in highly destabilizing ways.

These same physical principles place practical limits on improvements in U.S. space-based intelligence capabilities. As best as can be determined from the public record, the NRO currently operates up to three spy satellites in each of three categories: the Keyhole series of optical satellites, the Lacrosse/Onyx series of radar satellites, and the Misty series of stealth satellites.[198] The optical satellites already have extremely high resolution (reportedly about ten centimeters), while the radar satellites can collect lower-resolution images even at night and in cloudy weather. The satellites need to be close to the Earth to take high-quality pictures, but this means that they can view only a narrow swath of the Earth, that they rapidly move over a given ground-track, and that they are not in position to see the same location again for several days. With only a small number of satellites in orbit, these systems are well suited for certain strategic purposes, such as early warning of troop movements, arms control verification, or episodic observation of other targets of interest, but they do not work well for some desired tactical purposes, such as tracking moving targets, keeping suspect sites under continuous surveillance, or providing warfighters with total battlespace awareness.

Increasing the number of advanced imaging satellites would reduce revisit time over high-value targets and expand the total amount of ground area that could be observed in a given time period. Given the difficulties in the NRO's FIA program, the stopgap approach has been to pay industry to launch a new generation of commercial high-resolution satellites and to allow their imagery with better than 0.5-meter resolution to be sold only to the U.S. government. DigitalGlobe launched its first WorldView-1 satellite in 2007, and GeoEye (formerly Orbimage and Space Imaging) plans to launch its first satellite in early 2008. These advanced satellites will provide some improvements over the current generation of commercial imagery satellites, such as the ability to differentiate between different types of large military vehicles or to identify the location of an observed object with an accuracy of a few meters. But commercial firms are unlikely to launch many of these higher res-

198. Little is known about the capabilities of the stealth satellites in the Misty program. The objective is to prevent adversaries from calculating when any U.S. satellite is in position to observe their activities, but amateur astronomers have sometimes been able to observe and track the first two Misty satellites launched in 1990 and 1999. The program drew congressional attention in 2004 when it was learned that the projected cost for launching a third Misty satellite by the end of the decade had almost doubled from $5 billion to $9.5 billion. That effort was reportedly cancelled in 2007. See Jeffrey Richelson, "Satellite in the Shadows," *Bulletin of the Atomic Scientists,* May/June 2005, 26–33; and Mark Mazetti, "Spy Director Ends Program on Satellites," *New York Times,* June 22, 2007.

olution satellites because they cost much more yet collect less imagery and the best data can be sold only to one customer.[199]

Achieving qualitative breakthroughs in the U.S. military's ability to identify, understand, and address emerging security challenges would require a much more extensive program. Because satellites cannot see inside buildings, efforts to dramatically improve the utility of space-based imagery for finding and neutralizing chemical or biological agents would most likely involve taking much more frequent pictures throughout the construction of anything that might one day become a suspect site, then frequently checking for external signs of suspicious activity. The notion of an "unblinking eye in the sky" scanning the entire global for evidence of suspicious activity that requires closer scrutiny would also require vastly expanded capabilities. If satellites with one-meter resolution were used and could image both day and night, then roughly 200 satellites would be required for a six hour revisit time, assuming that every spot on the Earth would be imaged at least once every six hours. As many as 1,200 satellites would be needed to be able to image every spot on the Earth at least once an hour. Hundreds of terabytes (10^{12}) of raw data would be collected on the six-hour schedule, while petabytes (10^{15}) would be collected on the one-hour schedule, creating downlink bandwidth bottlenecks and requiring ten- to fifty-fold increases over current U.S. imagery data processing and storage capabilities.[200] If a mix of U.S. and foreign government and commercial imagery satellites were used, lack of common standards would create potential compatibility problems. As the number of different sources of imagery data increase, integrating the information into a single coherent picture or measuring changes at the same location over time becomes more and more difficult. Finally, mountains of archived and fresh satellite data would be of little value without a comparable investment in highly skilled imagery analysts, a perennial problem in the intelligence community.[201]

Another transformational goal for space-based intelligence would involve using radar satellites to find, track, and target moving objects such as mobile missile launchers, especially in places where U.S. aircraft cannot easily operate. Current plans call for the Air Force, the NRO, and the NGA to jointly develop a constellation of synthetic aperture radar (SAR) satellites. First launch is projected for 2016, but significant technical hurdles remain. Differentiating between stationary and moving objects is much more difficult from space than with airborne radar because from the perspective of a satellite in a 1,000 km orbit fixed objects on the Earth's surface are rotating at 15,000 miles per hour and mobile

199. Marty Kauchak, "Eyes for a Sharper Image," *Military Geospatial Technology* 4, No. 5 (November 19, 2006), http://www.military-geospatial-technology.com/article.cfm?DocID=1787.

200. David E. Mosher and Steve Fetter, "The Limits of Space," CISSM working paper, Center for International and Security Studies at Maryland, forthcoming.

201. Dwayne Day, "In Defense of the Beleaguered Spy Satellite," *The Space Review,* June 14, 2004, http://www.thespacereview.com/article/161/1.

targets are moving only tens of miles faster. Other challenges include developing a large phased-array radar that could survive launch and deployment in space and finding a practical way to meet high power requirements. These technical challenges do not seem insurmountable, but the cost of deploying enough satellites to achieve the unique benefits of a military space radar system might well be. Although the program is still in its earliest stages, soaring cost estimates and budget constraints have already caused the Air Force to reduce the planned number of satellites from twenty-two to eight and to scale back promises about system capabilities.[202]

The CBO used information from unclassified studies of previous space radar concepts to assess three architectures using five, nine, and twenty-one satellites with 40-square-meter radar arrays and one architecture comprising nine satellites with 100-square-meter radar arrays. The CBO analysts determined that for life-cycle costs ranging from $25 billion to $90 billion, a space radar system could increase the availability of high-resolution SAR imagery and shorten response time but could not provide continuous SAR coverage of a given region. Even at the theoretical optimal limit for signal-processing algorithms, the less expensive architectures would be able to detect targets moving at or below 20 miles per hour less than 30 percent of the time, while the detection probability for the 21-satellite constellation would be about 60 percent. Perhaps the most valuable capability attributed to space radar by its proponents, the ability to continually track a mobile missile launcher or other moving target until it could be destroyed, would require at least four or five times more satellites than are currently under consideration, with a corresponding multiplication of costs.[203]

202. The GAO's 2006 report on defense acquisitions described the space radar program as involving twenty-two satellites, costing about $23 billion, and being able to "find, identify, track, and monitor moving or stationary targets under all-weather conditions and on a near-continual basis across large swaths of the Earth's surface." See GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs* (Washington, DC: GAO, 2006), 105, http://www.gao.gov/new.items/d06391.pdf. The 2007 version of the same report described a much smaller eight-satellite system that could "provide persistent, all-weather, day and night surveillance and reconnaissance capabilities in denied areas" at a projected cost of $17.5 billion. See GAO, *Defense Acquisitions*, 127. No information was provided about the technical characteristics of these satellites, so the cost estimates in the GAO reports cannot be compared to the CBO estimates outlined in CBO, *Alternatives for Military Space Radar,* prepared for the Senate Subcommittee on Strategic Forces of the Committee on Armed Services, January 2007, http://www.cbo.gov/ftpdocs/76xx/doc7691/01-03-SpaceRadar.pdf.

203. CBO, *Alternatives for Military Space Radar.* The range of cost estimates for the five, nine, and twenty-one satellite configurations reflect differences not only in the number of satellites but in the size of the radar array and in assumptions about advances in signal-processing algorithms and cost growth in this space acquisition program. In the mobile missile launcher scenario, the number of satellites needed to find the mobile launcher before it left the launching location and to track it continually until a strike aircraft could destroy it depends on the size of the satellites' radar array, their signal processing capabilities, and their maneuverability. The CBO did not estimate the cost of a satellite constellation that could track mobile targets, but it would likely be $100–$200 billion or more, comparable to recent cost estimates for the two most expensive defense acquisition programs, the Joint Strike Fighter and the Future Combat Systems.

Some applications are best done using a medium number of satellites in medium earth orbits (MEO). Because satellite-based navigation requires simultaneous signals from at least four locations, the GPS, GLONASS, and Galileo systems are designed to provide global coverage with twenty-four to twenty-seven satellites. China currently uses three GEO satellites plus signals from ground stations to provide regional navigation services, but it wants to add two more GEO and thirty "non-GEO" satellites in order to have a global navigation satellite capability. Under current circumstances, the primary danger for satellites in MEO comes not from human action but from nature—that is, from the physical challenges of operating for extended periods of time in the harsh radiation environment around the Van Allen belts. Despite well publicized concerns about inexpensive jammers that can interfere with local reception of GPS signals, interfering with the satellites themselves is difficult: they are too high to reach using a modified missile for a ground-based KE ASAT attack; they do not use optical sensors that can be dazzled; and they have various forms of passive protection.[204] If space-based missile defense interceptors or ASATs were deployed, navigation satellites would be more vulnerable to direct attack, but many satellites would have to be disabled or destroyed to significantly degrade the system's capabilities.[205]

From an economic standpoint, a single worldwide satellite navigation system operated as a global public utility would make more sense than multiple constellations with potential interference and compatibility problems. This is unlikely as long as system operators are directed to seek national security advantages by controlling access to different space-based positioning, navigation, and timing services. Current U.S. policy aims not only to ensure that its own military has more precise GPS information than other users do but also to prevent adversaries and terrorist groups from using *any* space-based positioning, navigation, or timing services, "particularly including services that are openly available."[206] No other country has declared the aspiration to control who can or cannot use navigation satellite information from systems that belong to somebody else, and technical factors make such selective denial difficult. Current European refusal to allow foreign participation in Galileo's decision-making body or to permit foreign access to its encrypted

204. See Wright, Grego, and Gronlund, *The Physics of Space Security,* 165–169.

205. Geoffrey Forden found that even if the six GPS satellites most relevant for service in Beijing stopped broadcasting, users in the region would still be able to see at least four satellites for all but roughly two hours per day. See "Appendix D: Sensitivity of GPS Coverage to Loss of One or More Satellites," in *Ensuring America's Space Security* (Washington, DC: Federation of American Scientists, 2004), http://www.fas.org/main/content.jsp?formAction=297&contentId=311.

206. The U.S. policy calls for improved capabilities to deny hostile access "without unduly disrupting" civil and commercial access to open signals outside the area of military operations, thus tacitly acknowledging that this type of counterspace operation would have major unintended consequences. The 2004 policy is detailed in OSTP, "U.S. Space-Based Positioning, Navigation, and Timing Policy: Fact Sheet," December 15, 2004, 3, http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf.

government-only Public Regulated Service is, however, a major reason why China, India, and Israel are all reconsidering their involvement and why China wants its own global system.

OVERALL ASSESSMENT

With cost, inherent difficulty and limited program progress all considered, it seems evident that the SPACECOM vision of dominance cannot meet the burden of proof to which it should be subjected. Likewise, the laws of orbital dynamics create complex tradeoffs among altitude, number of satellites, capability, weight, and cost that have not been realistically assessed either by the advocates of space dominance or those parts of the U.S. political system charged with analytical oversight and budgetary responsibility. Satellites designed to perform advanced missions are generally visible, fragile, and expensive, making them vulnerable to interference at a fraction of the cost and technical expertise needed to build, launch, and operate them. The traditional U.S. preference for some degree of mutual strategic restraint in space reflected the fact that offense is inherently easier than defense in space, so valuable, vulnerable satellites will benefit from organized protection against deliberate attack or inadvertent interference. But organized protection requires rules that are equitable and mutually beneficial, not a lopsided competition to use space for unilateral national advantage.

The current U.S. disinterest in equitable rules assumes that the United States will be able to outspend and out-innovate all potential rivals in space by such a large margin that the benefits of seeking full-spectrum space dominance will outweigh the added costs of using military means to protect U.S. and friendly space systems against asymmetrical attacks. No plausible multiple of current U.S. military space spending, however, is likely to produce 1) a space radar constellation that can track moving targets; 2) a revolutionary approach to space launch that can put satellites of many different sizes into space on short notice at a fraction of the current cost; 3) a constellation of space-based boost-phase missile defense interceptors; *and* 4) all the other capabilities needed for total space dominance. Nor is the expectation that commercial space will expand enough for the U.S. government to achieve SPACECOM's ambitions without investing huge sums of its own money realistic so long as export controls stifle international trade and the military remains the U.S. space industry's largest customer.

The more likely outcome of a sustained U.S. effort to dominate space for national military advantage is that incremental advances in U.S. capabilities will increase pressure on other countries to react by emulating, offsetting, or restraining the United States. So far, Russia and China have made the most visible moves related to these response options, simultaneously trying to improve their own space-based military support systems, to explore asymmetrical ways to neutralize advantages that the U.S. military gets or could gain from superior space capabilities, and to start PAROS negotiations. Each

response strategy has serious costs and risks, and it is doubtful that either country has yet made a decisive choice. Foreign speculation about external reasons for the Chinese ASAT test place differing degrees of emphasis on alternative response strategies by assuming that the objective is to deter U.S. attacks on Chinese satellites, to negate the U.S. information advantage in a regional conflict, or to underscore the risks that all space users will face if military activities continue to expand without additional rules.

The longer the United States rebuffs international pressure to restore strategic restraint, the further other countries are likely to go in their efforts to emulate or offset U.S. military space activities, making space a much more expensive and dangerous place to operate than it currently is. The United States could probably sustain its technological lead and budgetary advantage for decades, but the U.S. military space acquisition program appears to have passed the point of diminishing returns, whereas other countries could still make significant advances in their military space capabilities for some fraction of what the United States is spending. The number of satellites needing protection keeps increasing, but offensive and dual-use space technologies are advancing and spreading faster than purely defensive ones are. Thus, if U.S. space dominance is defined in relative rather than absolute terms and likely counterreactions are considered, even the less ambitious form of the SPACECOM vision appears increasingly unattractive.

Ineffectual pursuit of military space dominance carries high opportunity costs. At the most basic level, the U.S. attitude has hindered efforts to develop strong international rules to minimize space debris, manage space traffic, and allocate orbital slots in GEO.[207] The U.S. attitude has been a major obstacle to the most efficient and equitable approach to space-based navigation services—a single system operated as a global public utility with decision-making control shared among international partners. The U.S. position currently also precludes any realistic strategy for truly transformational uses of space. A system of remote sensing satellites that could provide comprehensive, detailed, and continuous coverage of the Earth could be immensely valuable for information-based strategies to address emerging global security problems, including the possibility of catastrophic climate disruption. Owens and Nye observed a decade ago that the uncontested acquisition of this type of capability required a strategic purpose with widespread legitimacy.[208] Given a better understanding that the number and cost of the necessary satellites are beyond the reach of even the richest individual country and that the

207. In June 2007, COPUOS approved debris mitigation guidelines, including a recommendation to avoid "the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stage or other activities that generate long-lived debris." These guidelines are useful, but nonbinding. They are available at "U.N. Space Debris Mitigation Guidelines," http://orbitaldebris.jsc.nasa.gov/library/references.html. For those interested in voluntary space coordination to minimize inadvertent risks, the next objective is to avoid collisions between space objects by improving space situational awareness, developing common rules of the road, and devising procedures to avert or handle dangerous incidents.

208. Nye and Owens, "America's Information Edge."

global commercial space industry will not spontaneously produce this type of capability any time soon, the only way to achieve a qualitative change in space-based information will be through close and committed cooperation with other space-faring countries.[209]

In short, the prospects for establishing decisive U.S. military control of space are too poor for that to be a reliable basis for security, and the provocation emanated to the rest of the world is too serious for unrestrained exploration to be indefinitely tolerable. Unrealistic zealotry on this topic promises to induce threats to U.S. space assets that otherwise would not exist. The ability of the U.S. government and indeed of the entire political system to impose appropriate analytic discipline is an unavoidable test of competence not yet passed. A minimum criterion for meeting that test is to subject the vision of dominance to active competition from an alternative conception based on the legacy of strategic restraint and equitable legal rules appropriate to a global security environment in which a wide range of states and nonstate actors have both the capability and the strong determination to use space for a continually expanding array of purposes.

209. A modest step in this direction was taken with the February 2005 agreement on a ten-year implementation plan for the Global Earth Observation System of Systems (GEOSS). The plan includes a vision of comprehensive and sustained Earth observations in order to help alleviate suffering and enhance well-being but includes no discussion of security applications except in the context of disaster management and sustainable agriculture. GEOSS is primarily a "conceptual and organizational framework" to encourage and coordinate the exchange of data from existing and future national remote sensing assets. The implementation plan includes no commitments for new satellites, no implementation body with any legal authority, and no mandatory financial contributions. The plan is available at http://www.earthobservations.org/docs/10-Year%20Implementation%20Plan.pdf.

The Possibility of Negotiated Protection

If the constructive use of space does unavoidably require international accommodation, as originally presumed, and if the pursuit of assertive national dominance is recognized as both unrealistic and provocative, then a major reformulation of current U.S. policy will be necessary and will require serious consideration of enhanced legal protection built upon the principles and legal obligations of the OST. If defeating belligerent reactions to an assertive policy of dominance is not feasible, then preventing such reactions by conveying credible reassurance, which almost certainly would require legally binding commitments, becomes vital. The relative capacity and recent behavior of the United States is such that simple declarations of benign intent and voluntary behavioral guidelines are inadequate to assuage concerns. Responsible assessment of the situation must therefore anticipate eventual negotiations to elaborate the existing rules regulating space activity in order to assure equitable protection for all countries. If dominance is not possible, enhanced legal protection is not merely a necessary concession to other countries but rather the predominant interest of the United States itself.

Although proposals designed to improve legal protection have been advanced in the PAROS discussions in the CD, none of these appears to have been taken seriously enough by the U.S. government to have been systematically reviewed. Since the suspension of ASAT negotiations with the Soviet Union in 1979, the United States has refused to engage in any formal discussion of additional regulation, and the notoriously laborious process of working out acceptable details has not even started.

The central issues and applicable principles are nonetheless reasonably apparent, and plausible outcomes can be visualized even if the exact content and timing cannot be. Formal negotiations designed to provide more robust legal protection for space activities would seek:

- to prohibit deliberate interference with legitimate space assets and dedicated preparations to undertake interference;
- to prohibit the deployment in space of all types of weapons;
- to distribute the burdens and benefits of verification-related monitoring in an equitable manner; and
- to define the legitimate limits of space-based support for military operations.

A fully developed legal regime would require acceptable specification for all of these elements and would undoubtedly be difficult, but not impossible, to achieve. Even a partial set of these measures, however, could compete with

partial realization of the dominance vision as a basis for security, and the process of deliberation would be a necessary means of pursuing practical consensus on the underlying principles in question—most notably, the balance between competition for national advantage and collaboration for mutual protection.

PROHIBITING INTERFERENCE

The central problem to be addressed is the threat of interference posed by the inherent vulnerability of all space assets. Protecting them against the natural hazards of the environment is difficult enough. Providing physically assured protection against deliberate assault is unfeasibly expensive and, thus, for practical purposes all but impossible. Because the capacity to do damage is conferred by the capacity to launch any object or to project any significant energy source to orbital altitude, protective rules cannot preclude destructive potential in space while also allowing legitimate use. Any space asset could be used as a weapon against others within reach of its maneuvering or illuminating capability. Therefore, practical protective rules would have to focus more on behavior than on capability. Most of the proposals that have been advanced for additional regulation of military space activities feature a prohibition on deliberate acts of interference and on dedicated preparations to undertake them. Some realization of that idea would undoubtedly be a basic objective of any formal negotiation.

The principle of prohibiting acts of interference in space can be expected to command widespread but not uncontested adherence. The history of accommodation between the original Cold War protagonists and the more recent infusion of space services into daily activities throughout the world have set a presumption that space is a venue for common use rather than antagonistic competition—more like a network of highways than a battleground. The contrary assertion by space warfare advocates that conflicts of national interest will inevitably dominate is not supported by the historical record and is not the prevailing public impression. Nonetheless, a candidate agreement prohibiting acts of interference in space and the testing and deployment of the means to undertake them would face demanding burdens of defining both the acts and means in question, of setting restrictions that would provide meaningful protection, and of demonstrating how compliance is to be determined.

A ban on interference would begin with a prohibition on any further tests or operational deployment of dedicated anti-satellite systems. Additional protection against direct acts of interference would address proximity and illumination. An acceptable agreement would presumably have to set buffer zones around space assets and prohibit any incursion into the zones by controlled orbiting objects not specifically authorized; it would also have to set tolerably low thresholds for illumination of space assets by remote energy sources, and it would have to prohibit interference with the communications channels to

and from satellites as the basic rule but would probably have to tolerate some degree of functional denial or disruption during wartime. Any legal exemptions for wartime interference with communications or imagery satellites should be of minimal duration and area of application, and their military value should be weighed against the increased difficulty of keeping the war limited once such attacks had occurred.[210]

The working out of agreed details for these provisions would undoubtedly be contentious but is feasible in principle. Exclusion zones and illumination thresholds can be defined that would prevent interference if they are honored. Deliberate violation could be detected and responsibility attributed by the methods used to monitor space launches and to track orbiting objects. The same features of the environment that impose inherent vulnerability—predictable orbits, cost of maneuver, and exposure to observation—also complicate stealthy attack by kinetic or explosive means, and satellites could be equipped with sensors that would detect and report destructive illumination.[211] The question is whether a regime of enforced transparency designed to prevent undetected or unattributed interference could overcome the legacy of secrecy originally imposed to hide the capacity for electromagnetic observation and electronic intercept. That is a matter of preference rather than technical feasibility, and the trade-offs involved are not severe under current circumstances. Concealing the exact capabilities of current satellites might be possible, but concealing their existence or basic purposes is not. If parties to an agreement prohibiting acts of interference wish to set a high standard for verifying compliance, they could do so without having to reveal much if anything not otherwise known. They would have to reveal, however, the existence and ownership of all satellites.

OUTLAWING PREPARATIONS FOR INTERFERENCE

In support of a ban on acts of interference, a negotiated protective agreement would presumably also seek to prohibit dedicated preparations for interfer-

210. One reason attacks on military support satellites were avoided during the Cold War was the belief that U.S. and Soviet leaders could do a better job of keeping a crisis from spinning out of control and keeping a limited war from escalating to an all-out nuclear exchange if they had good information about what was happening and could easily communicate with each other and with their military commanders. Another reason is that many satellites that provide military support services for one country also provide important services for many other customers who might not be involved in the initial hostilities but who could be drawn in if interference with that satellite threatened their national interests.

211. A space-based ASAT could be secretly attached to its target (a parasitic ASAT), it could trail close behind its target in the same orbit, it could be placed in a distant part of the same orbit, or it could be placed in a crossing orbit. Given current satellite sizes and launch detection and space surveillance capabilities, the United States might be able to hide a space-based ASAT, but whether any other country could do so with confidence is doubtful. Over time, the prospects for stealthy space-based ASAT attacks will depend on the progress of satellite miniaturization compared with the development and spread of launch monitoring and space surveillance capabilities. See Wright, Grego, and Gronlund, *The Physics of Space Security,* 151–154.

ence so as to protect the arrangement against sudden collapse. A cease-fire agreement or the desist-from-firing variant is not robust if loaded guns are left in the hands of combatants.

That supportive provision would undoubtedly be more difficult to achieve. A prohibition on any further tests or operational deployment of designated anti-satellite weapons would effectively contain any threat from that source, because their development up to this point has been rudimentary. But the U.S. program for ballistic missile defense poses more of a problem. Exoatmospheric interception of ballistic missile warheads also enables attack on satellites in LEO, and technical reasons lead some to believe that this is in fact the most credible mission. Kinetic interception of missile warheads can readily be defeated by accompanying decoys, but that tactic cannot be as effectively applied to space assets, which must emanate detectable signals over extended periods of time in order to perform their functions. Intense political commitment to missile defense in the United States and strategic resistance to it in China would undoubtedly be a major impediment to a ban on anti-satellite systems. That is not a valid reason for categorically rejecting the idea, but the issue is one that would require more consequential decisions than governments of any type are usually willing to make.

The central question is whether to attempt an inherently questionable distinction between ballistic missile defense and anti-satellite functions or whether to pursue an arrangement that encompasses both problems. The former approach might involve agreed limits on the testing and deployment of missile defense interceptors (number of launchers and their location) but would be burdened by the basic fact that a missile defense deployment of any size would pose a significant threat to the small number of sensitive satellites, each one of which is significant. The latter approach would be more venturesome and for that reason more interesting. A logical combined arrangement would require that any missile defense deployment be dedicated to global rather than exclusively national protection and that it be jointly operated to assure that commitment. Such an arrangement would not preclude the capability for satellite attack, but with suitable internal rules it would prevent operational preparation or actual execution of such attacks. Even dedicated advocates of missile defense might eventually warm to that idea. As a practical matter, the technical prospects of missile defense are so poor that establishing global legitimacy might well prove to be a necessary requirement for sustaining the effort.

BANNING FORCE APPLICATION WEAPONS IN SPACE

In addition to prohibiting acts of interference in space and dedicated preparations to undertake them, advanced measures of protection would have to include a categorical ban on all types of weapons deployed in space for possible use against terrestrial targets. Otherwise the prohibition on interference would create a legal sanctuary for initiating attack. Negotiating an explicit ban would require some agreed determination of what constitutes a weapon

and would have to contend with fertile imagination as to how deliberate damage might be inflicted. As a practical matter, however, the main problem would be conventional weapons of various designs intended for attack on the Earth's surface or in the atmosphere.

The idea of attacking surface and airborne targets from space is one of the more fanciful features of the dominance vision. At present, no specific weapons conception would plausibly compete with standard alternatives already available for those missions, but because the idea is especially venturesome it has acquired ideological status for some of its advocates and is a source of emotional alarm for those potentially threatened.[212] A formal ban on such weapons would be an exercise in reassurance that some are reluctant to give and many are eager to receive, but because there is no historical legacy to deal with and no development programs that have gone beyond the conceptual stage it would not pose as many immediate problems of definition and verification as would the other weapons categories. The ban would legally preclude the development of systems that countries would be unlikely to deploy once they carefully weighed technical, economic, and military considerations, but because it would constrain the exploration of feasibility it would be consequential. In terms of verification the ban would present the problem of determining that weapons development and deployment activities that are not being observed do not actually exist, and the principal difficulty would be that of setting an appropriate burden of proof.

SHARING THE BURDENS AND BENEFITS OF MONITORING

Verification, compliance management, and enforcement of various layers of prohibition to a high standard of assurance would require significant innovation and would be a major topic of formal negotiations. Relying solely on nationally controlled assets to detect violations would be unwise. No other country is currently able to match the extensive U.S. system for tracking space objects, and international space situational awareness is substantially dependent on information the United States agrees to share. Even the United States considers its existing space surveillance capabilities inadequate for current needs, let alone for monitoring compliance with new rules regulating military space activities. To the extent that deliberate interference with space assets or space-based weapons are considered to be significant threats, the basic capacity for monitoring space objects would have to be improved, and arrangements for distributing the resulting information would have to be worked out.

In an informal "non-paper" circulated in 2004, the Chinese and Russian delegations to the CD jointly reviewed the various proposals that have been

212. The concept that is currently receiving the most attention, at least in the unclassified literature, is the FALCON idea for a launch-on-demand reusable HCV. If the HCV were to become technically feasible, it would not fit within the traditional definition of a space weapon as something that has been placed in orbit and thus could raise challenging definitional questions if negotiators wanted the new rules to cover it.

advanced to assure compliance with a categorical ban on space weapons.[213] Some proposed measures have involved direct inspection of satellites and their supporting facilities prior to launch, while others have relied on remote observation of the launch itself and of subsequent activities in orbit. The document notes that France, Canada, and the former Soviet Union have each separately proposed the creation of an international space monitoring agency with the authority and capacity to conduct remote observation or perform direct inspection. The non-paper catalogs predictable objections to different verification schemes, including opposition to on-site inspection, resistance by states that have space surveillance capabilities to sharing that technology or the information from it, and reluctance to bear the financial burden. The non-paper suggests that the first step should be agreement on the legal commitments to be included in a new space treaty, which could be of value even without verification and which could lead to agreement on verification commensurate with the security value of the obligations.

The joint assessment also suggests what is evident; namely, that the prospects for any new legal arrangements to constrain and monitor military space activities would be determined primarily by the United States, which has not only the most-developed monitoring capability but also the largest interests at stake. The United States has made the greatest investment in space assets and is substantially dependent on them for conducting global military operations. The potential vulnerability of these assets to relatively unsophisticated attack presents a more significant threat than any other military establishment encounters in space, and the intrusive military missions that are enabled by these assets create the strongest incentive for others to engage in such attacks. A ban on space weapons would disproportionately benefit the United States, which therefore has the strongest reason to set and maintain exacting standards of verification. Because of the inherent threat the U.S. military presents to all other countries, the United States also has the strongest incentive to convey as well as to receive reassurance. Advanced verification would have both effects, and an inevitable principle of reciprocity would obtain, however unwelcome it might be to some: one must convey reassurance in order to receive it.

The basic means of doing so involve establishing broadly representative international participation in the space surveillance activities the United States currently conducts and in any future extension of those activities. As a practical matter the principal purpose of a verification arrangement is to assure that a prohibition on acts of interference and deployment of space weapons would not be seriously contested. Equitable participation in the verification arrangements would be the principal method of achieving that assurance. Monitoring capacities cannot guarantee detection of all conceivable violations at reasonable cost. An appreciable barrier must therefore be set such that the security risks associated with undetected violations are lower

213. "Verification Aspects of PAROS," a non-paper by Chinese and Russian delegations to the Conference on Disarmament, 26 August 2004.

than the security risks without a verified agreement, but the major effect is on the attitudes of those who engage in the monitoring process. International standards are in fact powerful once they are adequately established. Verification arrangements are the primary means of institutionalizing standards—that is, of embedding them in the routine operations of governments—and direct operational participation is necessary to accomplish that. All space-faring countries and presumably some representation of other space users would have to be directly involved if the principal effect is to be achieved. Involvement means that they would contribute to the monitoring effort, would participate in operational management, and would receive the data generated.

The Convention on Registration of Objects Launched into Outer Space, signed in 1975, already provides part of the legal foundation for an advanced verification arrangement. The convention makes states responsible for space objects that they launch, that they commission others to launch for them, or that are launched from their territory or facility, and it requires that states maintain a national registry of all such objects. The convention further requires that all states report to the UN Secretary General specific information from their national registry; notably, the time and location of launch as well as the orbital parameters and the general function of the object launched. Other agreements include more detailed launch notification and date-exchange obligations; most notably, a U.S.-Russian agreement to establish a Joint Data Exchange Center (JDEC) and the multilateral Hague Code of Conduct (CoC).[214] With an ambiguous definition of launching states and no compliance management provisions, the Registration Convention's central registry is far from complete. The United States has not been reporting the launch of intelligence-gathering satellites even though they are usually identified by amateur observers. The United States is not the only country that fails to take seriously its launch registry obligations, but it is the only major space-faring member of the Hague CoC that currently does not submit the recommended prelaunch notifications to other member states.[215] The United States should improve its own compliance and encourage others to do so by making access to U.S. space surveillance information contingent on compliance.

Beyond strengthening compliance with the Registration Convention and other relevant agreements, an advanced verification arrangement presumably would establish an international monitoring center to track space objects beyond their initial launch, to observe their interactions, and to warn of any events that appear to involve deliberate interference. Although operational

214. These agreements are detailed in Scott C. Larrimore, "International Space Launch Notification and Data Exchange," *Space Policy* 23 (2007): 172–179.

215. The State Department explanation is that the United States intends to use the same notification message to fulfill its obligations under both the Hague CoC and the JDEC agreements and that it does not want to submit the messages to Hague CoC members until the JDEC agreement is implemented. This explanation makes little sense. Russia has been submitting its notifications to the United States and other Hague CoC members but is threatening to stop its Hague CoC prelaunch notifications unless the United States begins them.

authority and primary monitoring responsibility would probably remain in national channels at the outset, creating an international center would force evolving specification of what information is to be shared and what the division of labor among the national governments is to be. An international center would also provide the institutional base for eventually internationalizing primary monitoring authority, an independent check on national activities likely to be necessary for credible reassurance. The growing problems of orbital debris and space traffic management might well give at least as strong an incentive for such an arrangement as the possibility of deliberate interference does and might even require higher-resolution observation capabilities.

SETTING LIMITS ON LEGITIMATE MILITARY SUPPORT

In the numerous international discussions anticipating space negotiations, Chinese diplomats have repeatedly indicated that some limitation on military support activities would have to be considered. They have not specified their concern and have not advanced any candidate proposal, but one can infer that the remarks refer to space support for the global strike missions the United States is explicitly developing. Because the principal weapons involved in those missions now or in the near term—advanced aircraft, cruise missiles, and conventionally armed ballistic missiles—would not be included in a formal ban on space weapons, the Chinese are raising the question as to whether some supplemental restriction on space-based military support would be necessary to restrict the capacity for sudden, long-range surprise attack. The unspoken implication is that China might not be willing to adhere to an interference ban or a space weapons ban without some agreed limitations on the future capabilities of force enhancement satellites or the conditions under which they can legitimately be used.

The Chinese suggestion generates such strong immune reactions within the United States that even those who support formal negotiations have generally avoided the topic for fear of political backlash against the other provisions. That the issue can indefinitely be avoided is doubtful, however. The prospects for global strike missions are significant enough to create a serious incentive for interference with military support assets, and that would have to be addressed in a fully developed regime of legal protection. Although no immediately apparent way exists to draw a boundary between support services that are legitimate and widely considered to be vital and support services that would be unacceptably threatening, some practical guidelines can be applied.

In any formal negotiation that included the topic, it would be appropriate to establish the presumption at the outset, perhaps as a condition for engaging in discussion, that it is legitimate for any country to use space for the kinds of passive military support activities that have traditionally been tolerated as conducive to international security and that any restriction to be considered would have to do with the possibility of substantial extensions of exist-

ing capabilities primarily associated with intrusive attack missions. Establishing such a presumption from the outset of negotiations would allow the topic to be addressed without appearing to compromise established rights. Also appropriate would be to focus discussion and perhaps limit the agenda to the most sensitive support services in question—primarily observation and tracking—and to exclude communications relay and navigation services that would be especially difficult to disentangle from legitimate activities. In the event that technological advances make possible very high resolution observation and real-time tracking anytime, anywhere, such that individual vehicles could be identified and followed for the amount of time required to attack from remote locations, some restraining rules would almost certainly have to be worked out. Otherwise heads of state and military commanders would perpetually be subjected to imminent personal threat. For the foreseeable future, expense alone will likely prevent blatantly objectionable levels of remote observation and tracking, but that practical fact should encourage formal discussion rather than substitute for it. The point would be to establish recognition of the principle and routine adherence to it, not to attempt to preclude any conceivable violation.

Immediate Implications

In the absence of some riveting incident that might command attention and require immediate action, the fundamental issues of space policy are unlikely to be resolved anytime soon. By itself the topic does not normally engage voting constituencies, mass media outlets, or national leaders, and that fact makes difficult the adjudication of the underlying collision of purpose within the specialty communities involved. Space policy is one of many emerging issues that pose such a problem. The specific issues in question are nonetheless embedded in broader concerns that do command prominent attention. The connection of space policy to terrorism, to the agonies of civil conflict, or to disputes over national nuclear weapons programs are not direct or obvious enough to be noted in public discussions of those subjects, but they are significant enough in operational terms to have relevance. Space services are vital in bringing remote military power to bear on all of these circumstances.

The opportunity for conveying reassurance is especially relevant. As the implications of globalization are gradually absorbed, it is becoming ever more apparent that raw power—that is, the capacity for destruction—is not the sole or even primary determinant of security in most circumstances of concern. The ability to contain violence and to defend basic legal order is determined more by establishing justification that is credible across cultural boundaries than by wielding coercive force. It is occasionally necessary to engage in violence in order to control it, but it is routinely necessary to nurture consensual acceptance of legal order on which the prevention of violence fundamentally depends. Any threatened or actual use of official force that runs counter to a country's own legal principles or to international legal rules affecting all countries thereby endangers its own purposes. Justification is an inevitable problem for the U.S. military establishment because of its preponderant capabilities, and that problem has been compounded by the projected aspiration of national military space dominance. The compounded effect, however, also creates an opportunity to provide reassurance. Serious concern is a precondition for significant relief.

The most readily available and most reasonably demanded form of reassurance would be to agree without preconditions to open formal negotiations on the control of space weapons. Because the United States has refused to engage in negotiations on that topic for nearly three decades, a willingness to do so would be considered significant, provided that the identity and behavior of the negotiators and the institutional support given to them conveyed an impression of good faith. Establishing a formal negotiating process would also have the effect of subjecting the advocates of dominance to the discipline of competition within the U.S. government, and that in turn might stimulate broader attention and encourage more balanced judgment than has

recently been applied. The initiation of negotiations can be done on executive authority in the United States with no requirement for formal congressional approval or for specific substantive decisions. Responsible management of security policy requires that much at a minimum.

But the scope and significance of opportunity is much greater than the minimum requirement. Predictably, the United States will eventually require legitimizing international assistance to master communal violence in Iraq and elsewhere and will have to convey credible reassurance to countries beyond its current alliance system in order to secure that assistance. Also predictable is that the threat of terrorism will eventually compel much higher standards of managerial control over mass destruction technologies, especially nuclear explosives. As these imperatives are encountered and the potential interaction between them pondered, the vital importance of establishing global security accommodation for purposes of mutual protection will have to be acknowledged. The clandestine, dispersed forms of violence that currently pose the most troublesome threats could be much better contained by advanced monitoring techniques designed to control access to the means of mass destruction and to enable detection of especially dangerous operations. In particular, all nuclear explosives could in principle be continuously monitored, making terrorist diversion or any hostile use far more difficult to undertake than it currently is. Intimate collaboration among all the nuclear-capable states would be required to set up such an arrangement, however, and legacy deterrent practices would have to be subordinated to that purpose. As yet no official effort to explore the possibility has begun, but the latent danger of dispersed explosives under conditions of endemic violence can be expected to force serious consideration at some point. The fundamental problem with the concept of dominance and the likely cause of its ultimate demise is that it does not comprehend the implications of the shift in the scale and character of threat that is occurring under the conditions of globalization.

The operational rules that would be the focus of space negotiations do not directly address these emerging forms of threat, but a formal negotiation would engage the central issue of global security accommodation necessary to establish robust protection. If the major societies of the world and the globalizing economy on which they increasingly depend are to be protected against the debilitating destruction that violent dissidents are capable of inflicting, they will have to develop behavioral standards, monitoring capacity, and compliance mechanisms that keep the inherent danger within tolerable range. Because the services provided by space assets have become so important to human activities of all types, space negotiations are a natural venue for working out rules of accommodation in practical detail, thereby establishing the underlying principles. A negotiating process conscious of that broader significance does not appear to be an imminent prospect under the current political leadership in the United States, but it is a reasonable aspiration.

Contributors

Nancy Gallagher is the Associate Director for Research at the Center for International and Security Studies at Maryland (CISSM) and a Senior Research Scholar at the University of Maryland's School of Public Policy. Before coming to the University of Maryland, Gallagher was the Executive Director of the Comprehensive Test Ban Treaty Task Force and worked with the Special Advisor to the President and the Secretary of State on recommendations to build bipartisan support for U.S. ratification. She has been an arms control specialist in the State Department, a Foster Fellow in the Arms Control and Disarmament Agency, and a faculty member at Wesleyan University. Gallagher is the author of *The Politics of Verification* (Johns Hopkins University Press, 1999), the editor of *Arms Control: New Approaches to Theory and Policy* (Frank Cass, 1998), and the co-author with John D. Steinbruner, Elisa D. Harris, and Stacy M. Okutani of *Controlling Dangerous Pathogens: A Prototype Protective Oversight System* (CISSM, 2007). She has also written articles on space security, nuclear arms control and nonproliferation, and other topics related to global security. She received her B.A. in history from Carleton College and her Ph.D. in political science from the University of Illinois, Champaign-Urbana.

John D. Steinbruner is a Fellow of the American Academy of Arts and Sciences and co-chair of the Committee on International Security Studies of the American Academy. He is a Professor of Public Policy at the University of Maryland and Director of the Center for International and Security Studies at Maryland (CISSM). Steinbruner served as Director of the Foreign Policy Studies Program at Brookings from 1978–1996. He has also held various academic positions at Yale University, the John F. Kennedy School of Government at Harvard University, and the Massachusetts Institute of Technology. Steinbruner is currently the Chairman of the Board of the Arms Control Association. He has authored and edited a number of books and monographs, including *Controlling Dangerous Pathogens: A Prototype Protective Oversight System*, co-authored with Elisa D. Harris, Nancy Gallagher, and Stacy M. Okutani (CISSM, 2007); *Principles of Global Security* (Brookings, 2000); *A New Concept of Cooperative Security*, co-authored with Ashton B. Carter and William J. Perry (Brookings, 1992); and *The Cybernetic Theory of Decision* (Princeton, 1974, reissued with new preface in 2002). His articles have appeared in *Daedalus, Foreign Policy, International Security, Scientific American, the Washington Quarterly*, and other journals. Steinbruner received his A.B. from Stanford University and his Ph.D. in political science from the Massachusetts Institute of Technology.

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